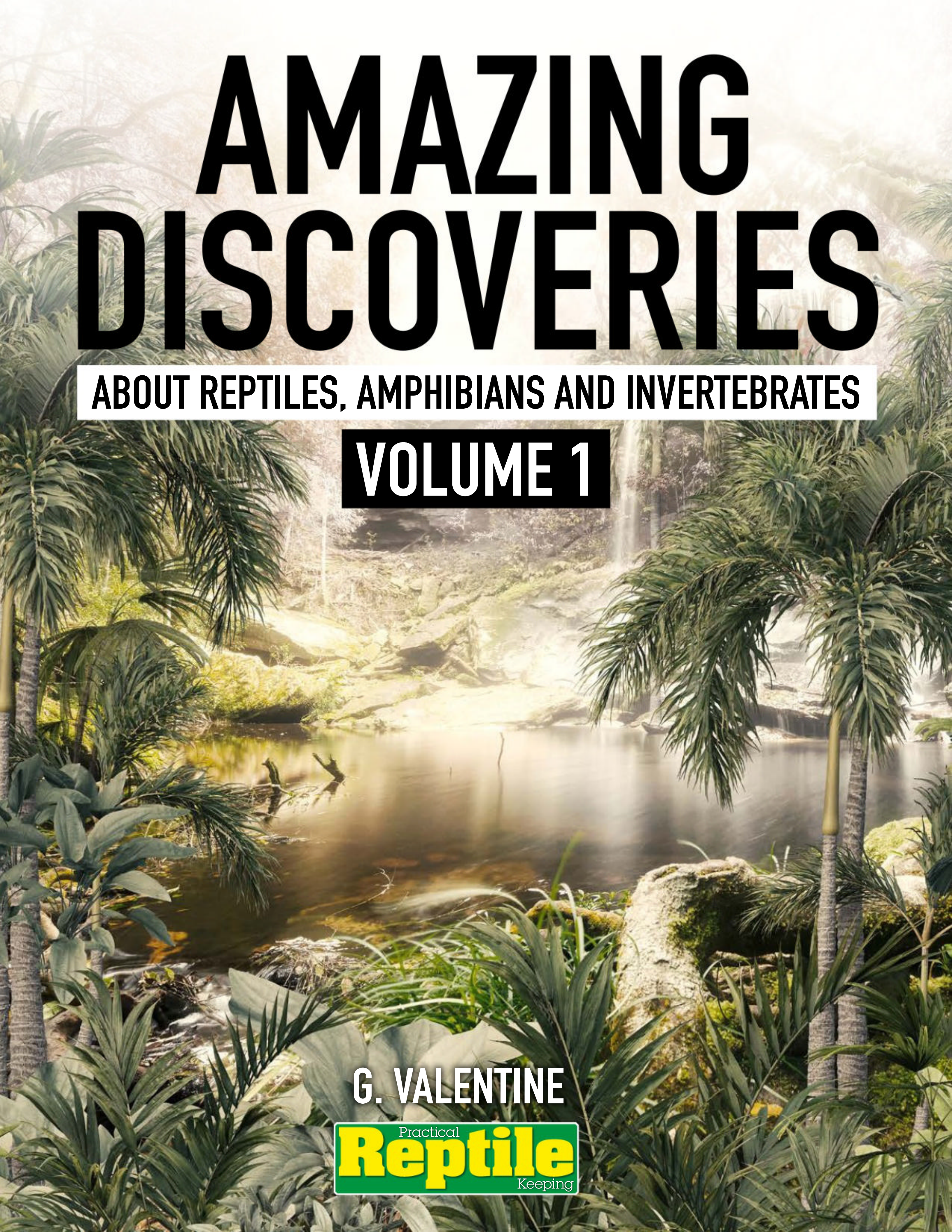

AMAZING DISCOVERIES

ABOUT REPTILES, AMPHIBIANS AND INVERTEBRATES

VOLUME 1

G. VALENTINE

Practical Reptile Keeping

VISIT…

LANZAROTE
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AMAZING DISCOVERIES

ABOUT REPTILES, AMPHIBIANS AND INVERTEBRATES

VOLUME 1

It is often overlooked how fast our knowledge about reptiles, amphibians and invertebrates continues to grow, revealing not just the existence of new species, but also amazing insights into the lifestyles and biology of these groups. Here are some of the most recent remarkable findings in this field. Don't miss G.Valentine's News and Views round-up that appears every month in the magazine, if you are keen to read the very latest information.

David Alderton

David Alderton,
Editor, *Practical Reptile Keeping*
www.practicalreptilekeeping.co.uk

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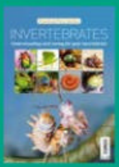
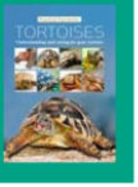


REPTILE HEALTHCARE

TALES FROM THE REPTILE HOUSE



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New Australian snake faces an uncertain future

A team of biologists led by The University of Queensland's Associate Professor Bryan Fry has discovered a new species of bandy-bandy snake, which is now known to science as *Vermicella parscauda*. The scientific paper describing this new species may only just have been published, but unfortunately, the reptile in question is already believed to be in danger of extinction, because of extensive bauxite mining in the area where it occurs.

This find was made at Weipa, on the west coast of the Cape York Peninsula. Interestingly, DNA studies have revealed that it is actually more closely to the bandy-bandies which live in western Australia, rather than the related species found on the Cape York Peninsula. This new discovery brings the number of recognised bandy-bandy species to seven in total. They are so-called because of their distinctive patterning, and are also known as hoop snakes because of their markings.

A lucky find

Professor Fry explained how this surprising chance discovery occurred when the team was actually undertaking sea snake research. "The bandy-bandy is a burrowing snake, so Freek Vonk from the Naturalis Museum and I were surprised to find it on a concrete block by the sea," he admits. "We later discovered that the snake had slithered over from a pile of bauxite rubble waiting to be loaded onto a ship.

"On examination by my student, Chantelle Derez, this bandy-bandy turned out to be a new species, which is both visually and genetically distinct from those found on the Australian east coast and parts of the interior."

Searching subsequently in the surrounding area, the team found another specimen in its natural habitat near Weipa, and a third that had been killed by a car close to the mine. Two more previously unidentified specimens were then discovered in museum collections, adding up to a tally of five individuals from the same small area.

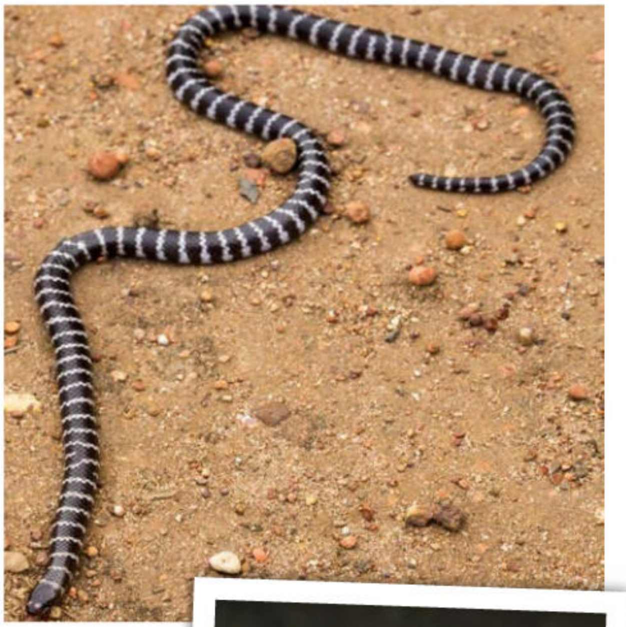
Under threat

Professor Fry admits, however, that he fears this new species could already be in trouble. "Bauxite mining is a major economic activity in the region, and it may be reshaping the environment to the detriment of native plants and animals," he says.

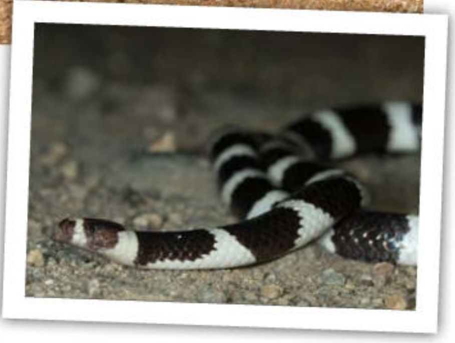
"The importance of such discoveries goes beyond simply documenting what is out there, as venoms are rich sources of compounds that can be used to develop new medications. Every species is precious and we need to protect them all, if only because we can't predict where the next wonder-drug will come from."

Lifestyle

Bandy-bandies as a group are relatively small snakes, growing to about 1m (3ft) in size, and have a highly specialised, subterranean and seemingly nocturnal lifestyle. Being mildly venomous, they hunt mainly blind snakes, and so are described as ophiophagous - a trait shared with Asia's king cobra (*Ophiophagus hannah*) and the king snakes (*Lampropeltis* species) of the Americas. In conclusion, Professor Fry points out: "The discovery of this enigmatic little snake is symptomatic of the much more fundamental problem of how little we know about our biodiversity and how much may be lost before we even discover it."

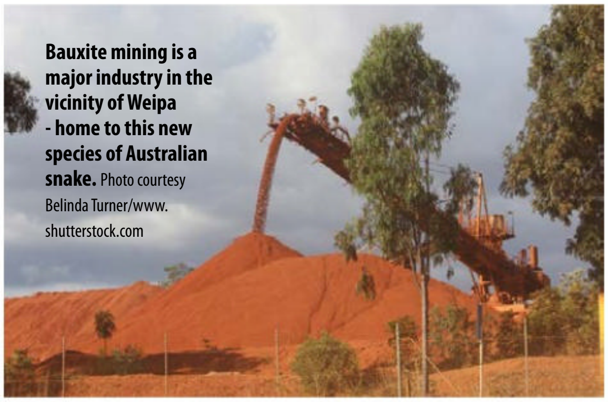


The new species of bandy-bandy. Photo courtesy University of Queensland.



The common bandy-bandy (*V. annulata*) has the widest distribution of all the species forming this genus. Photo courtesy Trent Townsend/www.shutterstock.com

Associate Professor Brian Fry on the hunt for more examples of the new species near Weipa. Photo courtesy University of Queensland.



Bauxite mining is a major industry in the vicinity of Weipa - home to this new species of Australian snake. Photo courtesy Belinda Turner/www.shutterstock.com

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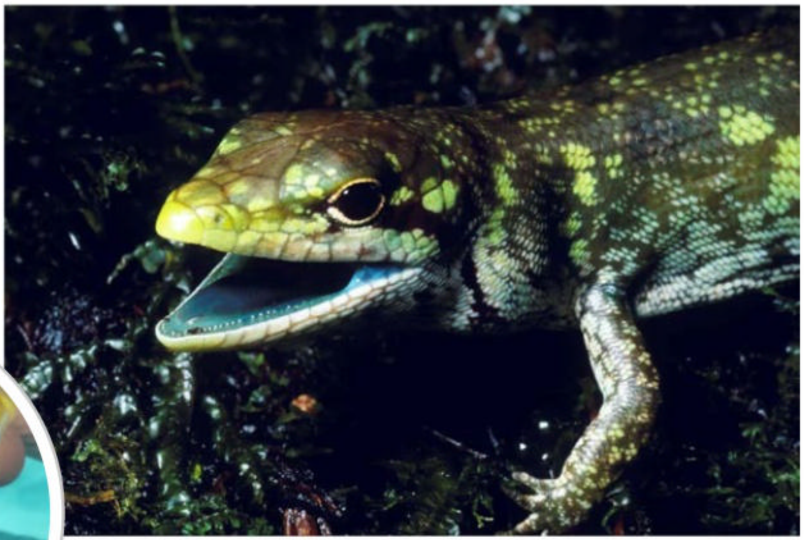
The green-blooded lizards



➤ **Confined to New Guinea, *Prasinohaema prehensicauda* is a green-blooded lizard with high concentrations of the green bile pigment known as biliverdin in its body.** Photo courtesy Chris Austin, LSU.

You might have assumed all vertebrates have red blood, but you'd be wrong! Green blood is nevertheless one of the most unusual characteristics in the animal kingdom, but it's a distinguishing feature of a group of lizards found in New Guinea.

Members of the genus *Prasinohaema* are green-blooded skinks, whose muscles, bones and tongues appear bright, lime-green due to high levels of biliverdin (a green bile pigment), which is toxic and causes jaundice. Surprisingly, however, these lizards remain healthy with levels of green bile that are 40 times higher than what would be regarded as a lethal concentration in humans.

⮝ **Biliverdin is responsible for the green colouration of bile.** Photo courtesy kerale/www.shutterstock.com

"In addition to having the highest concentration of biliverdin recorded for any animal, these lizards have somehow evolved a resistance to bile pigment toxicity. Understanding the underlying physiological changes that have allowed these lizards to remain jaundice-free may translate to non-traditional approaches to specific health problems," explains lead author Zachary Rodriguez, who is studying for a doctorate under Prof Chris Austin in Louisiana State University's (LSU's) Department of Biological Sciences.

The possible value of green blood

Prof Austin has led many expeditions to the island of New Guinea to discover and document reptile and amphibian diversity, and along with Zachary Rodriguez and colleagues. he has been investigating the evolutionary history of green blood, which is a feature of several species of New Guinea lizard.

The team examined 51 species of skink, which included six species with green blood. Two of these were previously unknown to science. They discovered that there are four separate lineages of green-blooded lizards, and each probably had a red-blooded ancestor.

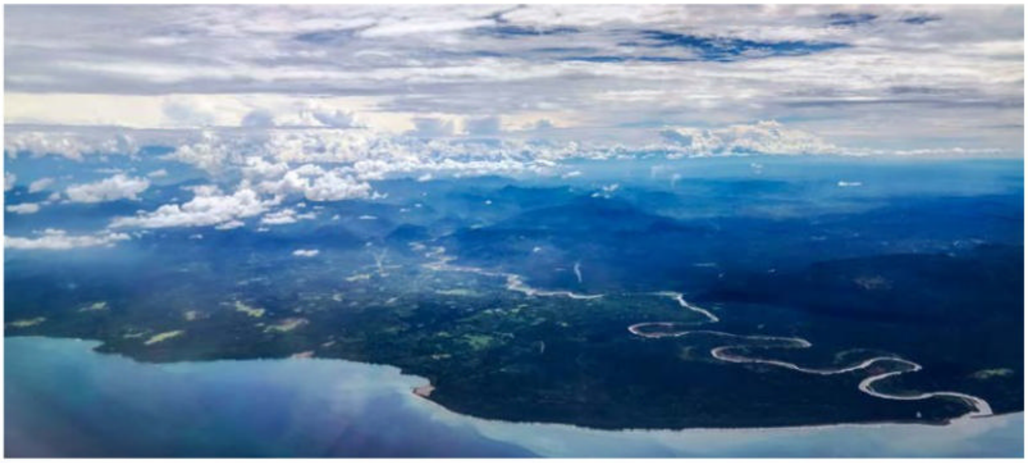
"We were excited by the complex history of these animals and surprised by the breadth of green-blooded lineages amongst lizards," Rodriguez admits.

Green blood most likely developed independently in various lizards, which suggests that it may have an adaptive value. Slightly elevated levels of bile pigments in other animals, including insects, fish and frogs, have played potentially positive roles in these animals. Previous studies have shown that bile pigment can act as an antioxidant scavenging free radicals as well as preventing disease during *in vitro* fertilisation. However, the function of green bile pigment in these lizards is still uncertain.

A cure for malaria?

"The green-blooded skinks of New Guinea are fascinating to me as a parasitologist because a similar liver product, bilirubin, is known to be toxic to human malaria parasites. Ongoing work with the Austin lab examines the potential effect of the green blood pigment on malaria and other parasites that infect these lizards," explains co-author Susan Perkins, curator and professor at the Sackler Institute for Comparative Genomics and the Division of Invertebrate Zoology, American Museum of Natural History.

The scientists examined DNA samples from 27 green-blooded lizards and 92 closely-related red-blooded lizards. They determined that red blood was the most likely ancestral state and that green blood has probably evolved four times. "Our next goal is to identify the genes responsible for green blood," Rodriguez adds.



⮟ **Mountains of the Madang Province Highlands in New Guinea where two species of green-blooded lizards live.** Photo courtesy Homo Cosmos/www.shutterstock.com

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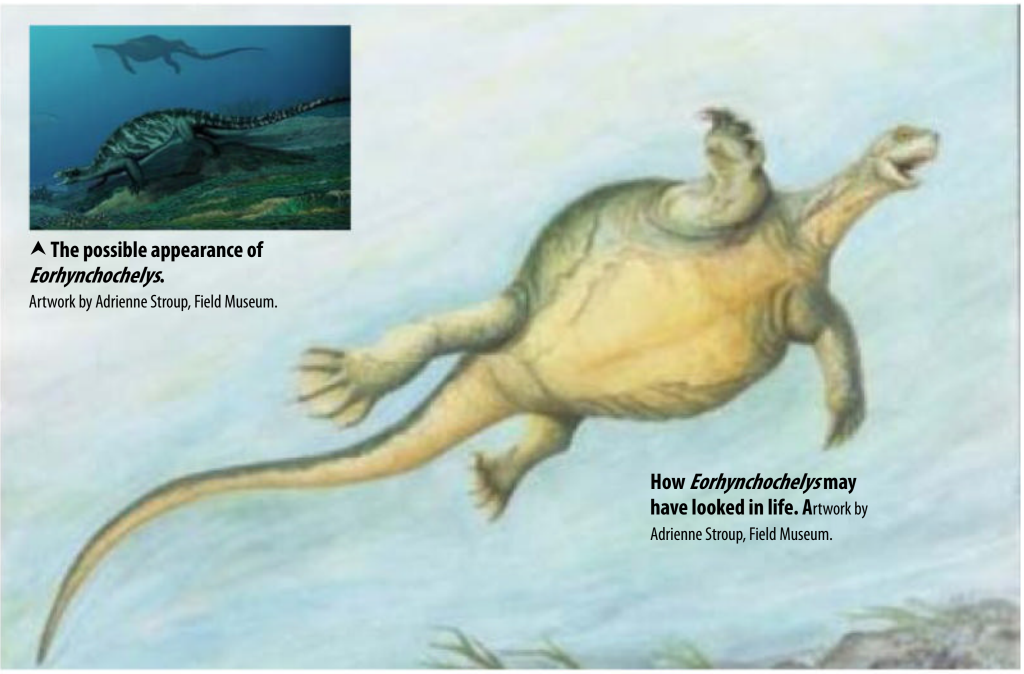
Zachary B. Rodriguez, Susan L. Perkins, Christopher C. Austin. **Multiple origins of green blood in New Guinea lizards.** *Science Advances,* 2018; 4 (5): eaao5017 DOI: 10.1126/sciadv.aao5017

The turtle without a shell



⌃ The possible appearance of *Eorhynchochelys*. Artwork by Adrienne Stroup, Field Museum.

How *Eorhynchochelys* may have looked in life. Artwork by Adrienne Stroup, Field Museum.

There are a couple of obvious key features that make a turtle unique: its shell, for one, and also its toothless beak. Now a newly-discovered fossil of a turtle that lived 228 million years ago is shedding light on how modern turtles developed these traits. It had a beak, but while its body was rather circular, its wide ribs hadn't grown to form a shell like we see in turtles today.

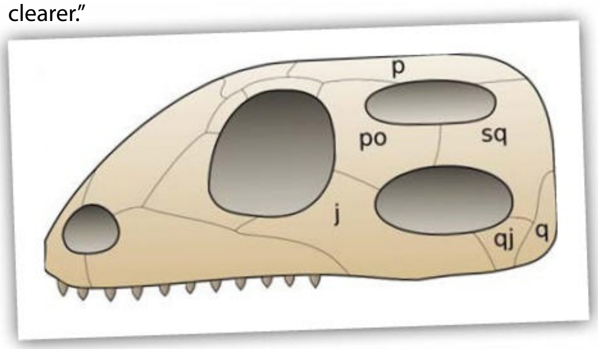
"This creature was over 1.8m (6ft) long, it had a strange disc-like body and a long tail, and the anterior part of its jaws developed into this unusual beak," says Olivier Rieppel, a palaeontologist at Chicago's Field Museum who has been investigating this bizarre fossil find. "It probably lived in shallow water and dug in the mud for food."

The new species has been christened *Eorhynchochelys sinensis* - a long name with a straightforward meaning! *Eorhynchochelys* (pronounced "Ay-oh-rink-oh-keel-is") means 'dawn beak turtle', translating essentially as the first turtle with a beak. The second part of the name, which is 'sinensis', means 'from China', and refers to the place where it was found by Li Chun of China's Institute of Vertebrate Palaeontology and Palaeoanthropology.

Variations on a theme

Eorhynchochelys isn't the only kind of early turtle that scientists have discovered though - there is another early turtle with a partial shell but no beak. Until now, it has been unclear as to how they all fit into the reptile family tree. "The origin of turtles has been an unsolved problem in palaeontology for many decades," says Rieppel. "Now with *Eorhynchochelys*, how turtles evolved has become a lot clearer."

⌄ A diapsid skull have two openings behind the eye socket, which are absent in an anapsid reptile skull. Artworks courtesy Preto(m).



The fact that *Eorhynchochelys* developed a beak before other early turtles but lacked a shell is evidence of what is often called 'mosaic evolution'. This is the idea that different physical traits can evolve independently from each other and at a different rate, and that not every ancestral species has the same combination of these traits.

Modern turtles have both shells and beaks, but the path that evolution took to get there wasn't represented by a straight line. Instead, some turtle relatives got partial shells while others got beaks, and eventually, the genetic mutations that create these traits both occurred in the same animal.

"This impressively large fossil is a very exciting discovery giving us another piece in the puzzle of turtle evolution," says Nick Fraser, from National Museums Scotland. "It shows that early turtle evolution was not a straightforward, step-by-step accumulation of unique traits but was a much more complex series of events that we are only just beginning to unravel."

Insight from the skull

Important details that were present in the skull of *Eorhynchochelys* have solved another turtle evolution mystery as well. For years, scientists were unsure if turtle ancestors were part of the same reptile group as modern lizards and snakes—diapsids, which early in their evolution had two holes on the sides of their skulls—or if they were anapsids, characterised by a lack of these openings.

The skull of *Eorhynchochelys* shows clear evidence that it was a diapsid. "With *Eorhynchochelys* having a diapsid skull, we know that turtles are not related to the early anapsid reptiles, but are instead related to evolutionarily more advanced diapsid reptiles. This is effectively cemented by this discovery, and the debate is over," adds Rieppel.

The team say that their findings, both about how and when turtles developed shells and their status as diapsids, will change how scientists think about this branch of the reptilian lineage. "I was surprised myself," Rieppel admits. "The discovery of *Eorhynchochelys* makes the turtle family tree make sense. Until I saw this fossil, I didn't buy some of its relatives as turtles. Now I do."

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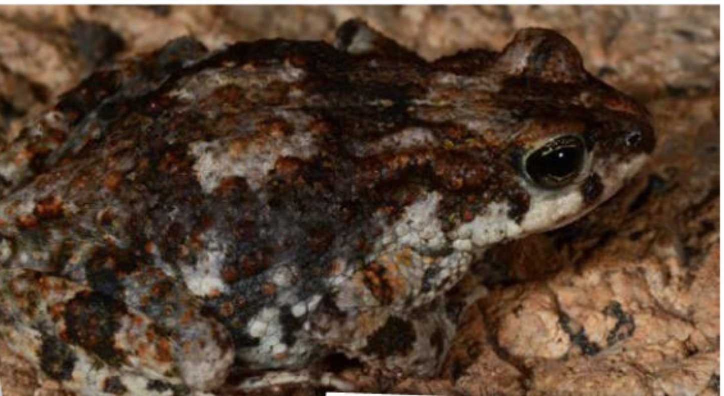
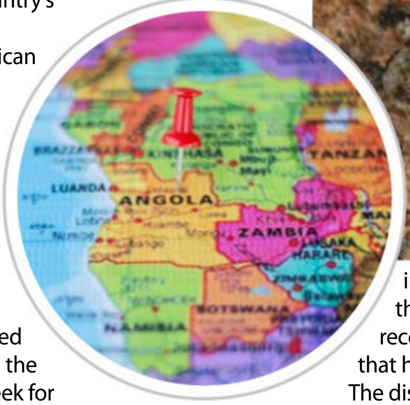
Unknown toad found on an Angolan mountain



➤ **The new earless African pygmy toad found on the Serra da Neve.** Photo courtesy Dr Ishan Agarwal.



⮝**Angola lies in the southwestern part of Africa.** Photo courtesy crazystocker/www.shutterstock.com

Decades of conflict in the African nation of Angola have hampered zoological exploration there for many years, but recently an international team, featuring scientists from the United States, Portugal and Angola itself has embarked on a series of expeditions to investigate the country's herpetofauna.

As a result, a new species of African pygmy toad has been discovered during an expedition to Angola's second highest peak, the Serra da Neve Inselberg.

This small toad is distinct among its close relatives in lacking ears, although other more distantly related toads also have no way of hearing.

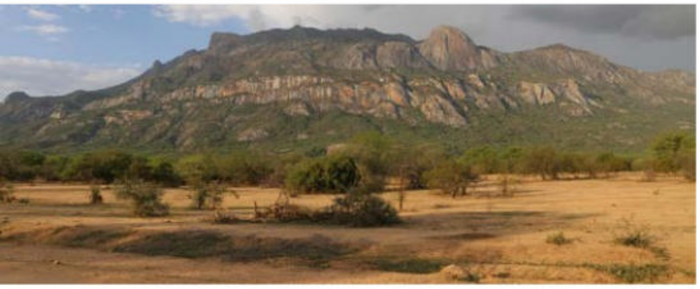
The new species has been named *Poyntonophrynus pachnodes*, with the description 'pachnodes' being Greek for 'frosty', referring to both the name of their homeland (which means "Mountain of Snow" in Portuguese) and the cool temperatures at the higher elevations where this amphibian occurs, nearly 1,500m (5000ft) above sea level.

Follow-up studies

After spending three weeks in the field, the scientists were then able to study the new amphibians with a combination of genetic and anatomical techniques. The team utilised DNA sequences to determine the relationship of the new earless species to other African toad species. They also used high-resolution computed tomography scanning (CT scanning) to look at the skeletons of these frogs and determine the extent of the loss of their auditory bones.

A strange but important environment

While closely related to other pygmy toads, this new species from Serra da Neve was found to lack both external and internal parts of the ear related to hearing in other frogs and toads. The combination of genetic and anatomical information revealed, however, that this new pygmy toad recently evolved from an ancestor that had a completely formed ear.



⮟ **The home of this new toad. This is Serra da Neve Inselberg in southwestern Angola, the second highest peak in the country.** Photo courtesy Dr Luis Ceríaco.

The discovery and description of a new species of toad found only in the mountains of Angola is surprising. Most frogs and toads prefer moist environments such as lowland tropical rainforests or cool montane forests and grasslands.

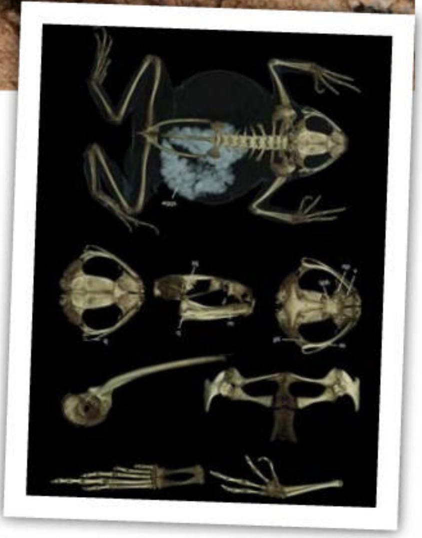
In contrast, most African pygmy toad species can be found in the arid region of southwestern Africa, encompassed by Angola and Namibia. With the addition of this new species, there are now five pygmy toad species present exclusively in this region. Other species are found across dry areas in southern and eastern Africa.

While many amphibians are not well-represented in this region, the African pygmy toads share their affinity for this type of arid environment with various lizards which are present only in this area. This finding highlights the region's importance for biodiversity.

A vital area for conservation

Namibe Province is among the better-explored regions of Angola, but little is known of the species found on its isolated mountains, which are known as 'inselbergs'. The Serra da Neve Inselberg is of special interest because of its isolation from other mountains, which allows for the evolution of unique species, such as this previously unknown pygmy toad. The recent field research at Serra da Neve and the discovery of this new species mean that this mountain will be considered a priority for conservation in the near future.

As its name suggests, this particular toad is small, being less that 31mm (1.2in) long, and coppery brown in colour. It lives among the rocks and leaves in dry open forests on Serra da Neve. While otherwise similar to other pygmy toads, the lack of ears makes this species distinct among its near relatives.



⮝**A CT scan of the skeleton of this previously unknown pygmy toad.** Photo courtesy Dr Edward Stanley.

It is presently unknown whether this species has a mating call and how it might otherwise hear. Various other anurans, including many species of toad, have also lost their ear structure through evolution.

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Investigating a deadly invader

A team of international scientists has discovered why brown tree snakes have become one of the most successful invasive species. The research team, led by University of Queensland (UQ) scientists, has been studying how a type of cat-eyed snake has been so effective at devastating native bird populations on the island of Guam.

Associate Professor Bryan Fry from UQ's School of Biological Sciences said the takeover began when the brown tree snake was introduced on the Pacific island during World War II. "The snake hitchhiked on troop carriers from the Australian region and has since driven multiple native bird species into extinction, with only three species now found on the island," he explains.

"The snakes' impact was so devastating, it ranks among the worst pests of all time."

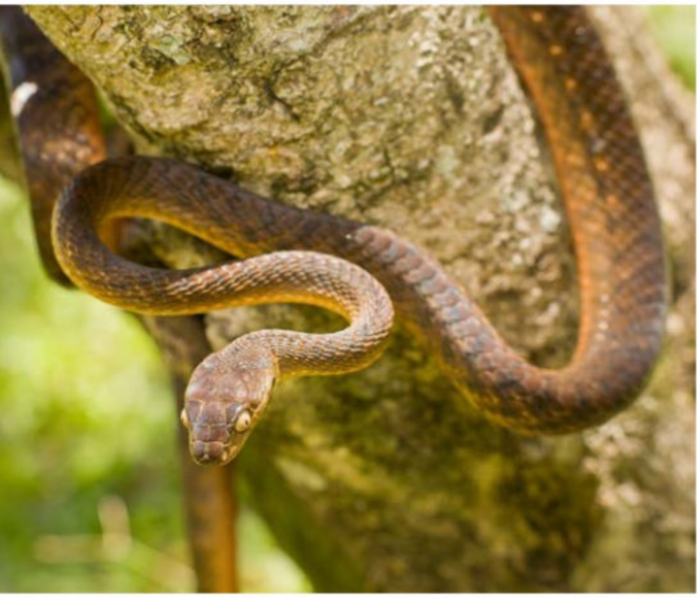
The brown tree snake (*Boiga irregularis*). Photo courtesy University of Queensland.

The small island of Guam lies way out in the Pacific Ocean, north of New Guinea. Map courtesy Yarr65/www.shutterstock.com

A new insight

The team, including UQ PhD students Daniel Dashevsky and Jordan Debono as well as researchers from Florida State University, investigated the species' toxin, which is particularly venomous to birds. "The brown tree snake's venom, while not dangerous to humans, is 100 times more toxic to birds than to mammals," Dr Fry says. "It contains a toxin that's made up of two smaller toxins joined together, which is a feature that was believed to be unique to brown tree snakes.

"However, Daniel and Jordan's research has revealed that this is not the case and in fact, any cat-eyed snakes belonging to the genus *Boiga* would have caused similar devastation. It's just that this particular species was transported to Guam by accident."



Brown tree snakes are essentially arboreal, as their name suggests, and they specialise in hunting birds. Photo courtesy Janelle Lugge/www.shutterstock.com

Hawaii under threat

Cat-eyed snakes evolved in Africa and rapidly spread across the Indian subcontinent, throughout southeast Asia, and extended their range to Australia, with the team finding the snake's toxin type was responsible for its explosive natural spread.

"For the last 80 years or so, for the brown tree snake at least, this biological advantage has been aided by the introduction of air travel," Dr Fry said.

"The US government is still flying military planes from Guam to Hawaii and there is therefore still the potential for the snakes to hitchhike.

"They have been intercepted in airports in Hawaii in the past, so if these direct flights are allowed to continue, there's a possibility they could get to Hawaii and wipe out resident avian species there, like they did on Guam.

"Now we know more about the snake's basic biology, however, so we can help in developing a smart approach to preventing and managing this and other invasive species," adds Dr. Fry.

Dr Bryan Fry holding a relative of the brown tree snake, which is a black and yellow cat-eyed snake. Photo courtesy University of Queensland.

Further reading

Daniel Dashevsky, Jordan Debono, Darin Rokyta, Amanda Nouwens, Peter Josh, Bryan G. Fry. **Three-Finger Toxin Diversification in the Venoms of Cat-Eye Snakes (Colubridae: Boiga).** *Journal of Molecular Evolution,* 2018; DOI: 10.1007/s00239-018-9864-6

Dracula ants can move faster than any other animal!

According to a new study, the Dracula ant (*Mystrium camillae*), can snap its mandibles at speeds of up to 90m per second (equivalent to over 200mph), making it the fastest moving animal ever recorded! Researchers believe that the high impact force generated by such movements is probably used as part of their predatory or defensive behaviour.

“These ants are fascinating as their mandibles are very unusual,” says University of Illinois animal biology and entomology professor Andrew Suarez. “Even among ants that power-amplify their jaws, the Dracula ants are unique. Instead of using three different parts for the spring, latch and lever arm, all three are combined in the mandible.”

▲ A Dracula worker ant, originating in Malaysia.
Photo courtesy Steve Shattuck from Canberra, Australia.

▶ The mandibles of the Dracula ant (*Mystrium camillae*) are the fastest-known moving animal appendages.
Photo courtesy Adrian Smith.

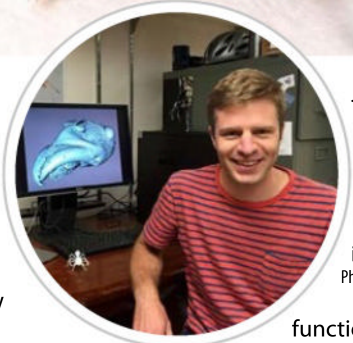
Why mouthpart speed matters

Unlike trap-jaw ants, whose powerful jaws snap closed from an open position, Dracula ants power up their mandibles by pressing the tips together, spring-loading them with internal stresses that release when one mandible slides across the other, similar to a human finger snap, according to the researchers.

“The ants use this motion to smack other arthropods, most likely stunning them, smashing them against a tunnel wall or pushing them away. They can then be transported back to the nest, and fed to the ants' larvae,” Suarez explains.

“Scientists have described many different spring-loading mechanisms in ants, but no one knew the relative speed of each of these mechanisms,” adds colleague Frederick Larabee said. “We had to use incredibly fast cameras to see the whole movement. We also utilised X-ray imaging technology to be able to see their anatomy in three dimensions, to better understand how the movement works.”

▼ Professor Andrew Suarez and his colleagues studied the speed and mechanical characteristics of the Dracula ant.
Photo courtesy L. Brian Stauffer.



◀ Fredrick Larabee, a postdoctoral researcher at the Smithsonian National Museum of Natural History, has been working as part of the team investing these ants.
Photo courtesy Frederick Larabee.

Just a slight modification

The team also conducted computer simulations of the mandible snaps of different castes of Dracula ants to test how the shape and structural characteristics of the mandibles affected the power of their snap.

“Our main findings are that snap-jaws are the fastest of the spring-loaded ant mouthparts, and the fastest currently known animal movement," Larabee explains. "By comparing the jaw shape of snapping ants with biting ants, we also learned that it only took small changes in shape for the jaws to evolve a new function: acting as a spring.”

The team's future work includes examining how the ants use their mandibles in the field. “Their biology, how they capture prey and defend their nests, is still in need of investigation,” says Smith.

Further reading

Fredrick J. Larabee, Adrian A. Smith and Andrew V. Suarez. **Snap-jaw morphology is specialized for high-speed power amplification in the Dracula ant, *Mystrium camillae*.** *Royal Society Open Science,* 2018 DOI: 10.1098/rsos.181447

Size matters in tortoises

➤ Tortoises vary considerably in size. Photo courtesy Don Mammoser/www.shutterstock.com

➤ The remains of different fossilised tortoises at the Central Natural Science Collections at MLU. Photo courtesy Markus Scholz/MLU.

Tortoises as a group occur in habitats ranging from deserts to forests, and can display remarkable variations in size. Some species evolved large body sizes with a shell length exceeding 1m (3ft) whereas others are no larger than 6-8cm (2.5-3.1in). Despite creating a particular interest in naturalists ever since the time of Charles Darwin, who saw giant tortoises on the Galápagos himself, the cause of gigantism in tortoises remains enigmatic.

The fact that all living giant tortoises occur on islands may suggest that their evolution followed the so-called 'island rule', meaning a trend toward dwarfism among large animals, and an increase in size or gigantism of small animals in these surroundings.

The impact of island life

An example of insular dwarfism are the pygmy elephants that used to live on islands in the Mediterranean. Their small size was probably an adaptation to the limited resources found within this restricted area. Insular gigantism is best exemplified by the famous dodo, an extinct flightless pigeon from Mauritius, that is likely to have evolved a large body size because it no longer faced predators here (until the arrival of humans).

Previous studies on living tortoises in this regard were partly inconclusive: giant size has been linked to the absence of predatory mammals on islands but it has been also proposed that tortoises were already giants when they reached the remote archipelagos. Since very few giant tortoise species survive to the present, these hypotheses are impossible to test without analysing extinct species with the help of the fossil record.

This has led Dr Evangelos Vlachos from the Paleontological Museum of Trelew, Argentina, and Dr Márton Rabi from the Martin Luther University Halle-Wittenberg (MLU), funded by the German VolkswagenStiftung, to assemble the most comprehensive family tree of extinct and extant tortoises so far assembled. The researchers analysed genetic data from living species together with skeletal data from both fossil and living tortoises.

This is the first study of such global scale to allow for investigating body size evolution in tortoises. The fossils reveal a very different picture from the past, compared with the present. Giant size evolved on multiple occasions independently in mainland Asia, Africa and Europe, as well as in North and South America at different times of the Earth's history. However, all of these species went extinct at the latest during the Pleistocene ice age, around 12,000 years ago.

Surprising findings

"The fossils highlight a large number of extinct mainland giant species and suggest that the evolution of giant size was not therefore linked to islands," says Dr Evangelos Vlachos. Instead, living insular giant tortoises, such as the ones from Galápagos and the Seychelles, more likely represent survivors of unrelated giant species that once inhabited South America, East Africa, and/or Madagascar.

"Giant tortoises may have been better island colonisers because they can tolerate water and food shortage during an oceanic dispersal for a longer period than smaller species. Giant tortoises have been reported to survive floating in the ocean for 740km (460ml)," says Dr Márton Rabi.

What led to the extinction of these mainland giants, however, remains enigmatic. For the Ice Age species, it may have been a combination of predatory (including human) pressures and climate change. Likewise it is unclear, if not the island rule, then what is driving tortoises to evolve repeatedly into these giant forms?

"We expect that a warmer climate and predator pressure play a role in the evolution of giant size but the picture is complex and our sampling of the fossil record is still limited," explains Dr Vlachos.

Mediterranean tortoises

An unexpected outcome of the study was that the Mediterranean tortoises, which are of course widely kept as pets, actually represent a dwarf lineage. Their ancestors turned out to be considerably larger than those alive today.

So what of the future? "Tortoises have been around for more than 55 million years and we are now able to better understand the evolution of this successful group. Today, however, out of the approximately 43 living species, 17 are considered endangered and many more are vulnerable largely due to human-induced habitat loss; this is a disappointing and worrying fact," adds Dr Rabi.

^ The sulcata or African spurred tortoise (*Centrochelys sulcata*) is the largest mainland species alive today.

Photo courtesy Vladimir Wrangel/www.shutterstock.ccom

⌄ Today's Mediterranean tortoises, like the Hermann's (*Testudo hermanni*) seen here, are significantly smaller than their ancestors.

Photo courtesy xpixel/www.shutterstock.com

Further reading

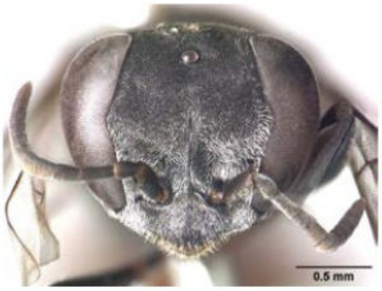
Evangelos Vlachos, Márton Rabi. **Total evidence analysis and body size evolution of extant and extinct tortoises (Testudines: Cryptodira: Pan-Testudinidae).** *Cladistics*, 2017; DOI: 10.1111/cla.12227

A range of new finds

The annual count is done, and researchers with the California Academy of Sciences recorded the discovery of 229 new species last year, extending across five continents and three oceans. The list features 120 wasps, 34 sea slugs, 28 ants, 19 fish, seven flowering plants, seven spiders, four eels, three sharks, two water bears, one frog, one snake, one seahorse, a moss, and a liverwort plant.

A swarm of spider-eating wasps

This year, 120 new wasps have been added to the tree of life. Hailing from Australia and New Guinea, these new members of the *Pison* genus are spider-eating bandits. Females paralyse spiders, stow them in the tiny compartments of their clay nests, and then lay an egg on top of each eight-legged prisoner. When the wasp larvae hatch, they then enjoy their first meal—a still-alive but immobilised spider. Emeritus curator of entomology Dr. Wojciech Pulawski has studied wasps since 1953. He spent 16 months studying the Australian *Pison* species in the field and another eight years on their formal description, naming several species after Aboriginal tribes. His thoughts on getting stung? "I hardly feel it," he says.

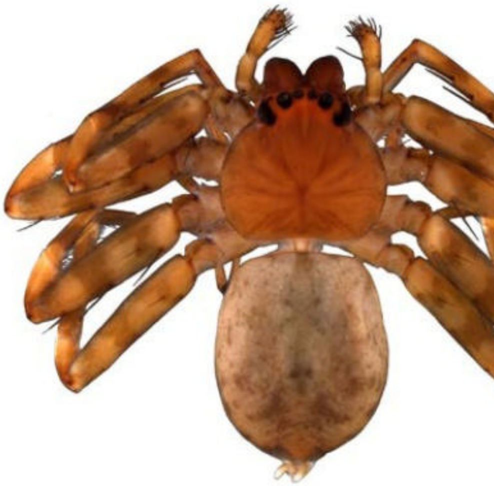


A head close-up of one of the new species, called *Pison orbitale*. Photo © Erin Prado/California Academy of Science.

***Psion* wasps have grisly feeding habits, in terms of rearing their young.** Photo courtesy Mark Marathon/Wikipedia CC BY-SA 3.0.

Spiders with the fastest spin on Earth

Spiders from the Selenopidae family were recently discovered to have the fastest leg-driven turn of any animal on the planet. This year, three new species join this fast-spinning group, including one from Egypt. Described by Academy post-doctoral researcher Dr. Sarah Crews and her colleague at the University of Tehran, this species was originally collected in the 1800s but only recently recognised as new to science when the team discovered it deep in the collection of the Oxford Museum. Four more additional spiders from Africa were also described last year by emeritus curator Dr. Charles Griswold.

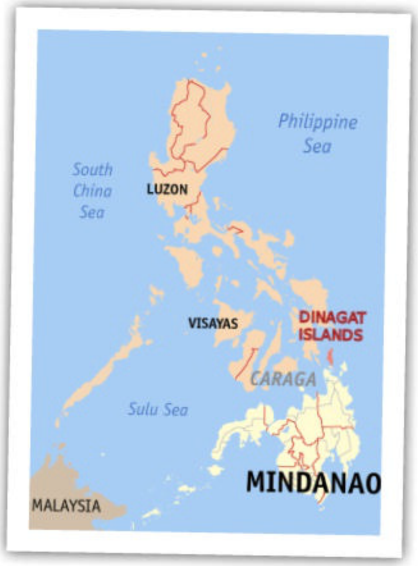


One of the new species of fast-spinning spider. Photo © Sarah Crews/ California Academy of Science.

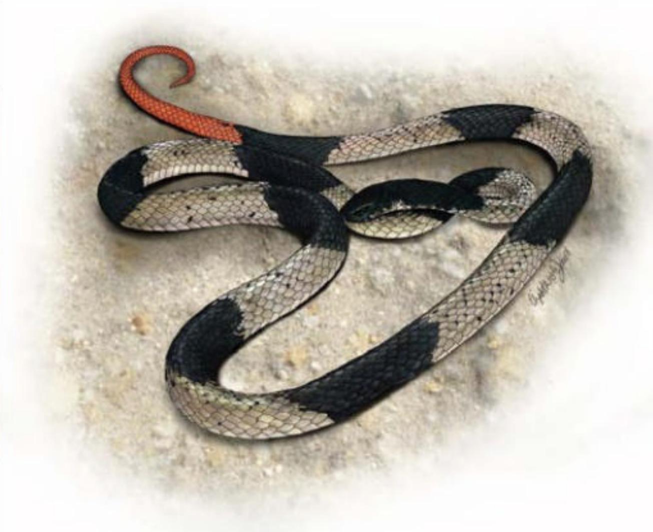
A mysterious coralsnake

A black-and-white banded, long-glanded coralsnake surprised researchers when they spotted it over 10 years ago on Dinagat Island, which lies in the south-eastern Philippines. The new species, formally described this year as *Calliophis salitan*, has a distinctive bright-orange tail unlike its blue-tailed relatives that inhabit the region. The newcomer, which belongs to a group of venomous Asian coralsnakes, is only found in the Philippines.

"The evolutionary origins of this new orange-tailed species remain a mystery," admits Dr. Alan Leviton, emeritus curator and Academy Fellow who described the new species with a team that included Academy research associate Dr. Rafe Brown from the University of Kansas (who also described a new frog this year). "The species might be more widespread than we think, there might be close relatives we haven't discovered yet, or



The location of the Dingat Islands in the Philippines. Map courtesy Eugene Alvin Villar (seav)/English Wikipedia CC BY-SA 3.0.

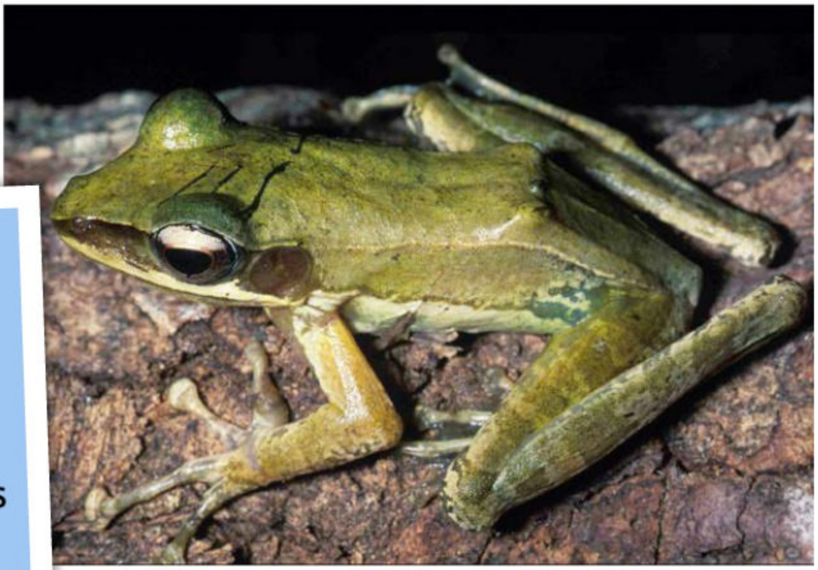


A new species of venomous coralsnake from the Philippines. Photo © E.F. Jones and The Herpetologists' League/California Academy of Sciences.

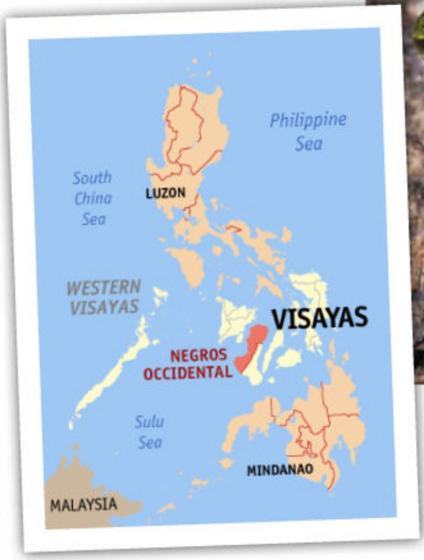
it could be the sole surviving member of a lost lineage," says Leviton. "Or, maybe orange is just the new blue!"

A frog in trouble

This newly-recognised frog from the Philippines inhabits Negros Occidental, where it is found in steams. It used to be thought that it was simply a variant of a previously known species from the island of Luzon, but more recent studied by Dr Rafe Brown have led to it being reclassified as a distinct species in its own right, thanks to characteristics such as its size and conspicuous pectoral markings. Unfortunately however, this amphibian is found in an area of West Visayas where there has been widespread deforestation of late, suggesting that its long-term survival could be threatened as a result, especially in view of its patchy distribution, and the fact that it is not commonly encountered in any event.



➤ **A new stream-dwelling frog from the Philippines.** Photo © Rafe Brown/California Academy of Science.



▲ **The area of the Philippines where the new frog is to be found.** Map courtesy Eugene Alvin Villar (seav)/English Wikipedia CC BY-SA 3.0.

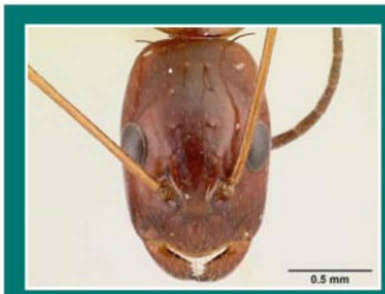
Ants with spider mimics

This year, 28 new species of ants join the tree of life in their march toward global domination. (Ants rival humans by having colonised almost all landmasses on Earth.) These new species are only found on the island of Madagascar. Several are part of the carpenter group, which inhabits every possible niche from the forest canopy to twigs and soil to rotten wood. "Carpenter ants live everywhere," says entomology curator Dr. Brian 'Ant Man' Fisher. "We're beginning to see that other insects, like spiders, mimic them in appearance. This might be for disguise, to help them hunt the ants, or for protection against predators that know carpenter ants to be distasteful." Fisher himself has made an impressive tally of over 1,000 new ant finds during his career.

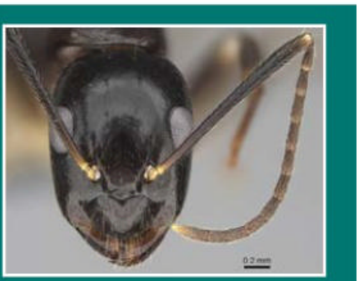
Still much to discover!

"Biodiversity scientists estimate that less than 10 percent of species on Earth have actually been discovered to date, when you take into account invertebrates" says Dr. Shannon Bennett, Academy Chief of Science. "Academy scientists tirelessly explore near and far, from the familiar forests in our backyards to remote locations as deep as 150m (500ft) beneath the ocean surface. Each discovery of a new species may hold the key to groundbreaking innovations in science, technology, or society and helps us better understand the diversity of life that makes up thriving ecosystems. These finds also highlight the critical role that we play as stewards of our one precious planet."

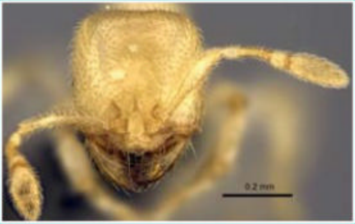
▲ **Carpenter ants can reduce trees to sawdust - and may attack buildings as well, as they generally prefer dead wood.** Photo courtesy NaC158/Wikipedia CC BY-SA 4.0.



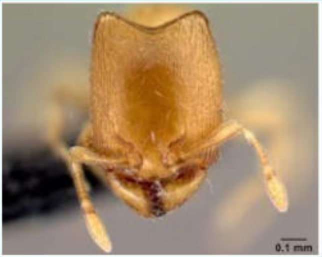
Camponotus raina (© Erin Prado).



Camponotus tanosy (© Michelle Esposito).



Carebara placida (© Frank Azorsa).



Carebara sampi (© Erin Prado).

The hidden advantage possessed by the blue-tongue skink

▲ **The unusually-coloured tongue of the blue-tongue skink helps to protect these lizards.** Photo courtesy Peter Waters/ www.shutterstock.com

When attacked, blue-tongue skinks open their mouth suddenly and as wide as possible to reveal their conspicuously coloured tongues. This surprise action serves as their last line of defence to save themselves from becoming prey says Martin Whiting, of Macquarie University in Australia, who conceived the study. The research revealed that the back of the northern blue-tongue skink's tongue is much more ultraviolet (UV)-intense and luminous than the front, and that this section is only revealed in the final stages of an imminent attack.

Blue-tongue skinks of the genus *Tiliqua* are medium-large sized lizards widely found throughout Australia, eastern Indonesia and Papua New Guinea. They are well camouflaged but their strikingly blue-tongues are distinct and are UV-reflective in species where this characteristic has been measured. When attacked, they open their mouths wide to reveal their tongues.

Why UV is significant and how skinks react

The research team set out to investigate the tactics that blue-tongue skinks use to ward off attackers, and focused on the largest of the blue-tongue skinks, which is the northern blue-tongue skink (*Tiliqua scincoides intermedia*). This omnivorous, ground-dwelling lizard of northern Australia is well-camouflaged thanks to the broad brown bands across its back. However, birds, snakes and monitor lizards - all animals thought to have UV vision, unlike ourselves - are among its main predators.

The researchers gathered information about the colour and intensity of different parts of the lizard's tongue, using a portable spectrophotometer to measure the tongues of thirteen skinks. The first exciting finding was that the blue-tongue is actually a UV-blue-tongue. The researchers then established that the rear of the skinks' tongues was almost twice as bright as the tips. When a predator approached, the skinks would remain camouflaged until the very last moment, before opening their mouths widely and revealing their highly conspicuous UV-blue-tongues.

▼ **The stage at which the lizard reveals its tongue is crucial. An eastern blue-tongue skink is shown here.** Photo courtesy Gordine N/ www.shutterstock.com

The next part of the study involved simulating 'attacks' on these lizards using model (fake) predators. The team used a snake, a bird, a goanna (monitor lizard), a fox plus a piece of wood as a control. The model predator attacks were simulated within a controlled environment.

Key observations

"The lizards restrict the use of full-tongue displays to the final stages of a predation sequence when they are most at risk, and do so in concert with aggressive defensive behaviours that amplify the display, such as hissing or inflating their bodies," explains researcher Arnaud Badiane. "This type of display might be particularly effective against aerial predators, for which an interrupted attack would not be easily resumed due to loss of inertia."

The more intense the attack and the greater risk that they were experiencing, so the more full-tongue displays the animals were seen to use, and they would reveal more of their tongues at the same time. Such displays were also most often triggered by attacking birds and foxes, rather than by snakes or monitor lizards.

▼ **The rear of the tongue is much brighter, in terms of UV light, than the tip, although this is not obvious to our eyes.** Photo courtesy ladyphoto/www.shutterstock.com

"The timing of their tongue display is crucial," adds Badiane. "If performed too early, a display may break the lizard's camouflage and attract unwanted attention by predators, increasing the predation risk. If performed too late, however, it may not deter predators."

Further information

Badiane, A. *et al* (2018). **Why blue tongue? A potential UV-based deimatic display in a lizard.** *Behavioral Ecology and Sociobiology* DOI: 10.1007/ s00265-018-2512-8

Moving snakes may not aid their conservation

A pioneering study by the University of Kent on the effects of relocating adders due to development has found that males will not stay put in their new surroundings, but will disperse from their release site – with one even going so far as to return to his original home range!

All native reptiles in the UK are protected by law, which means that those found to be present on sites scheduled for development are often moved to alternative habitats. Reptiles are frequently the targets of these translocations but there is little information on their fate or how their behaviour compares to individual animals that are left where they are.

For the study therefore, researchers Darryn Nash and Professor Richard Griffiths from Kent's Durrell Institute of Conservation and Ecology tracked adders (*Vipera berus*) translocated from a development site in Essex. Some of these snakes were fitted with external radio tags and tracked for a period of 10 days during the spring and summer. The movements of the translocated adders were compared to those of 'resident' snakes already present at the release site.

What was discovered

Translocated males exhibited significantly greater average daily movements than those that were resident. Furthermore, all translocated males undertook long-distance, unidirectional movements away from the release site. One of the males even returned to the area from which it had been moved, a distance of over 0.5km (546yd) which involved crossing large areas of unsuitable short grassland habitat. This could have exposed the snake to predators.

▲This study was facilitated by the fact that adders are unusual snakes, being sexually dimorphic, so it is possible to distinguish visually between the sexes. Males (as shown) are greyish with black markings, whereas females are brownish shades. Photo courtesy David Osborn/www.shutterstock.com

▲Female adders were much more sedentary, following translocation. Photo courtesy Jon Webster/www.shutterstock.com

▼Adder being tracked. Photo courtesy Richard Griffiths.

Furthermore, the research also showed a significant difference between how male and female adders reacted to being moved. Translocated males had significantly larger total ranges of movement than resident animals. In contrast, all translocated females remained within 50m (55yd) of the point of release.

Professor Griffiths explains: "It is clear that moving adders due to development is not as helpful to their conservation as people think. Our research suggests the dispersal of male snakes from the release site may increase the risk of mortality of snakes that have been moved from development sites and reduces the likelihood of establishing a new population. It may be time for a different approach. Encouraging the establishment of new home ranges within the boundaries of release sites may need mechanisms to prevent dispersal immediately following release."

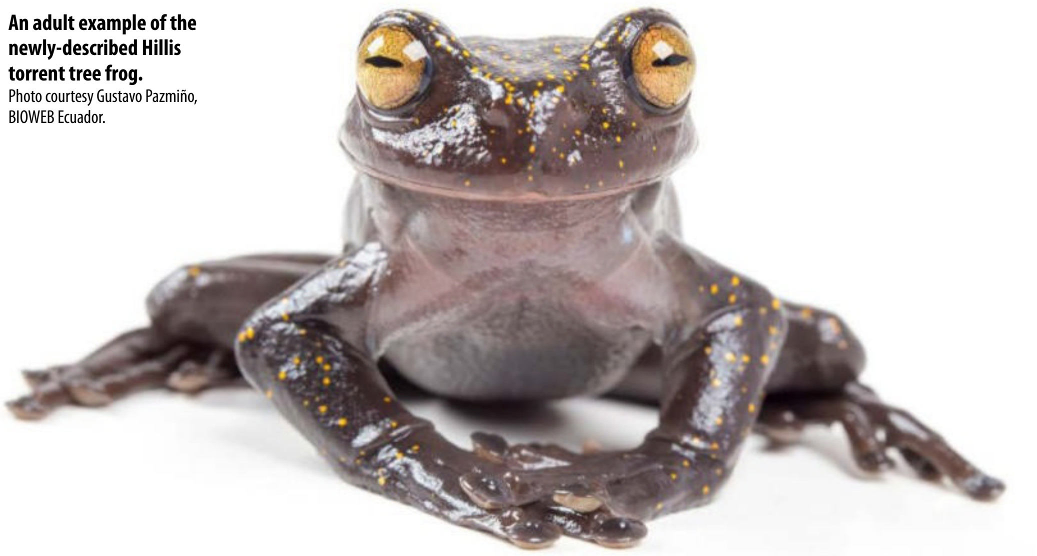
Further information

Darryn J. Nash, Richard A. Griffiths. **Ranging behaviour of adders *(Vipera berus)* translocated from a development site.** *Herpetological Journal,* 2018; 28 (4)

Extraordinary tree frog discovered in the Andes of Ecuador

A new tree frog species has been discovered during a recent expedition to a remote tabletop mountain at Cordillera del Cóndor, a largely unexplored range in the eastern Andes on the border between Ecuador and Peru.

“To reach the tabletop, we walked two days through steep terrain. Then, sweating and exhausted, we arrived at the tabletop where we found a dwarf forest. The rivers were blackwater, having a high content of organic material, and these frogs were living here, on branches of brown shrubs similar in colour to the frogs’ own. These amphibians were difficult to find, because they blended in so well with their background,” explains Alex Achig, one of the field biologists who discovered the new species.



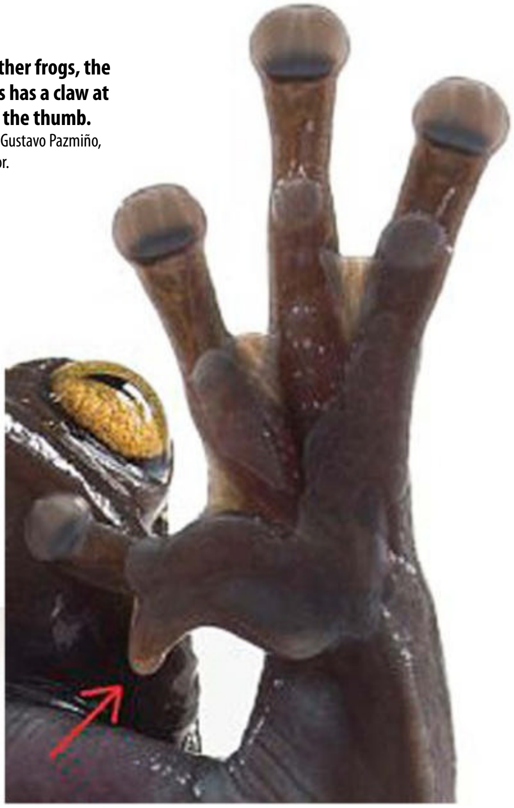
An adult example of the newly-described Hillis torrent tree frog.
Photo courtesy Gustavo Pazmiño, BIOWEB Ecuador.

A strange arrangement

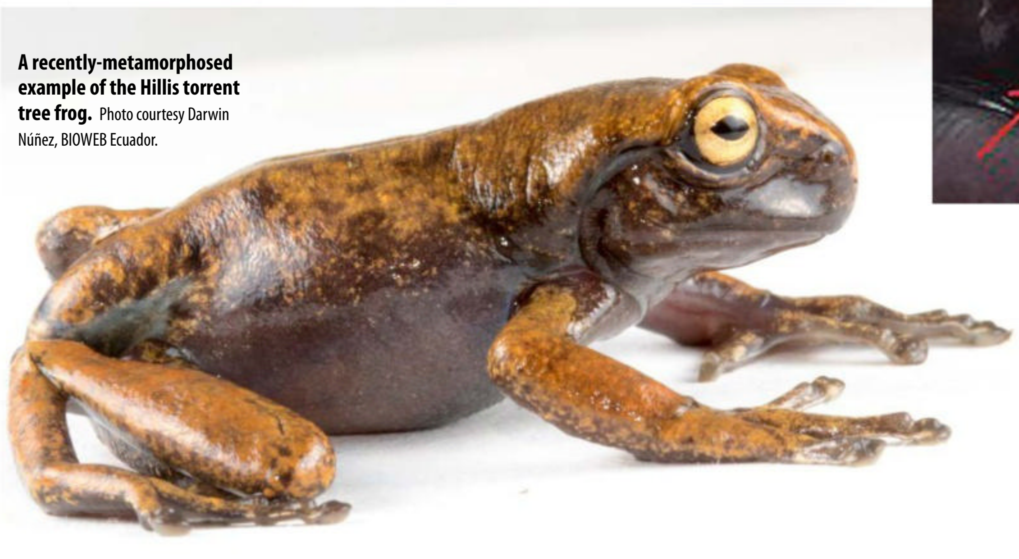
Curiously, the frog has an extraordinary, enlarged claw-like structure located at the base of the thumb. Its function is unknown, but it could be that it is used either as a defence against predators or as a weapon in fights between competing males. Having conducted analyses of genetic and morphologic data, scientists Santiago R. Ron, Marcel Caminer, Andrea Varela, and Diego Almeida from the Catholic University of Ecuador concluded that the frog represented a previously unknown species.

The scientific name of the new species, which is *Hyloscirtus hillisi*, honours Dr. David Hillis, a member of the National Academy of Sciences of the United States of America, who discovered three closely related frog species of the same genus in the 1980s, while conducting a series of field trips to the Andes of southern Ecuador. Throughout his career, Dr. Hillis has made significant contributions to the knowledge of Andean amphibians and reptiles.

Despite being newly described, the Hillis torrent tree frog is already potentially at risk of extinction. Its small area of distribution lies close to a large-scale mining operation run by a Chinese company, and habitat destruction in the region has recently been documented by the Amazon Conservation organisation.



➤ **Unlike other frogs, the new species has a claw at the base of the thumb.**
Photo courtesy Gustavo Pazmiño, BIOWEB Ecuador.

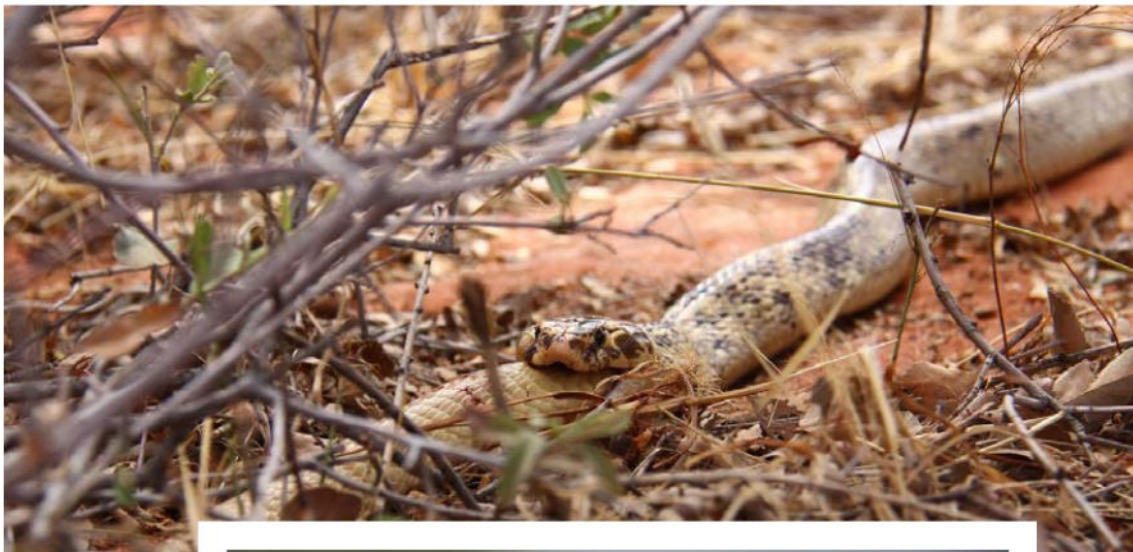


A recently-metamorphosed example of the Hillis torrent tree frog. Photo courtesy Darwin Núñez, BIOWEB Ecuador.

Further information

Ron SR, Caminer MA, Varela-Jaramillo A, Almeida-Reinoso D (2018) **A new treefrog from Cordillera del Cóndor with comments on the biogeographic affinity between Cordillera del Cóndor and the Guianan Tepuis (Anura, Hylidae, *Hyloscirtus*).** *ZooKeys* 809: 97-124. https://doi.org/10.3897/zookeys.809.25207

Cannibalistic cobras on the hunt



➤ **A Cape cobra male consumes a smaller male of the same species in southern Africa, a display of cannibalism thought to be rare among the species.** Photo courtesy Bryan Maritz.

➤ **Did cannibalism in African cobras develop from their display? A young Moroccan cobra (*Naja haje*) is shown here.** Photo courtesy Kristian Bell/ www.shutterstock.com

Researchers in South Africa's Kalahari Desert found a large male cape cobra devouring another smaller male of the same species. Surprised by what was thought to be a rare event, they then decided to investigate how common and widespread cannibalism was in cobras.

Apart from a few species, scientific understanding of snake diets is lacking. Snakes are elusive creatures that feed relatively infrequently, making feeding observations difficult to come by. Bryan Maritz, a researcher at the University of the Western Cape, explains: "This study highlights a renewed effort to quantify several aspects of snake natural history meaningfully, especially in poorly studied regions such as Africa."

While Cape cobras are known to eat other snake species – up to a third of their diet – recorded instances of Cape cobras eating individuals of the same species, known as conspecifics, has been extremely rare. Scientists have treated such reported observations as aberrant behaviour.

So, what caused this Cape cobra to attack and eat the smaller male of its kind? How often does this happen? Do all cobras take part in cannibalism?

An unexplored area

Maritz and fellow researchers in the southern African region were studying resource competition between two African snake species when they saw the rare cobra cannibalistic display that inspired them to conduct the new study. This study provides a unique opportunity to examine how they hunt and eat each other, a process which is known as ophiophagy.

The description of 'cobra' is typically applied to about 30 species, six of which were included in the study. Results suggest that not only do wild cobras frequently eat other species of snake, accounting for between 13-43 percent of their diet, but furthermore, cannibalism may be surprisingly common as well, given that five of the six species displayed the behaviour.

➤ **Left: study co-author Robin Maritz inspects a sociable weaver nest for cobras. Right: a Cape cobra peers down from a sociable weaver nest.** Photos courtesy of Bryan Maritz.

More questions raised

Interestingly, Cape cobras ate conspecifics in surprising abundance – the only species they consumed more frequently was the puff adder. Additionally, the researchers only found males engaged in cannibalism events, as prey or predator, hinting that this might impact intrasexual competition. This raises the question of whether cannibalism evolved from a male-male combative behaviour, considering that male-male combat in cobras typically includes biting.

Understanding how snakes interact with not only other species, but also with individuals of their own kind, can provide a basis for learning about more complex behaviour in different scenarios. If their ecosystem warms drastically and food becomes scarcer, will snakes engage more often in cannibalism?

If cannibalism drives snakes to select for larger sizes, what effect will that have on the other kinds of prey they eat? Maritz hopes that "improved understanding of snake ecology and feeding in general will help to highlight the ecological functional roles that snakes are performing in African ecosystems."

Further information

Bryan Maritz, Graham J. Alexander, Robin A. Maritz. **The underappreciated extent of cannibalism and ophiophagy in African cobras.** *Ecology*, 2018; DOI: 10.1002/ecy.2522

Giving a head start to tortoises

Research from the University of Georgia indicates that head-starting — raising a species in captivity and releasing it into a protected habitat after it has grown large enough to be less vulnerable to predators — is a useful intervention for boosting the state's gopher tortoise population, which has been declining in numbers for decades due to predation, poaching and loss of suitable habitat.

A key species

In total, 70 percent of head-started tortoises raised from donor eggs were still alive a year after release at Yuchi Wildlife Management Area (YWMA) in Burke County, according to field studies. "The gopher tortoise, which is Georgia's state reptile, is a keystone species whose burrows provide shelter for more than 250 other species," explains Tracey Tuberville, associate research scientist at the Savannah River Ecology Laboratory (SREL) and adjunct faculty at the Warnell School of Forestry and Natural Resources.

Despite predation risks at the release site, survival rates were higher than those reported for their wild counterparts, according to Daniel Quinn, a graduate student at SREL and Warnell during the research. He conducted two releases of yearlings at YWMA during consecutive years. The team said the second release was the largest tortoise release in the state to date.

"We initially released the tortoises into pens to acclimate them into the natural environment," Quinn explains. "This gives them time to construct a burrow and in theory, it reduces the predation risk."

▲ **Young gopher tortoises benefit from early protection from predators.** Photo courtesy Norma Stamp at Sunny Daze/ www.shutterstock.com

▼ **The burrows dug by gopher tortoises provide retreats for more than 250 other species, meaning that they - and the tortoises themselves - are very important within the overall ecosystem.** Photo courtesy Jay Ondreicka/www.shutterstock.com

GOPHER
TORTOISE
CROSSING

▲ **Other conservation measures in place include signs alerting drivers to the possible presence of these tortoises in the road.** Photo courtesy AnLuNi/www.shutterstock.com

The importance of tracking

Forty-two of 145 yearlings were radio tracked and monitored for a year following the 'soft' releases (as distinct from simply letting the hatchlings roam freely), providing information to assist future head-starting efforts.

Tracking data revealed that the juveniles demonstrated a strong rate of site fidelity, remaining together in a protected area, which also allows them to reproduce more effectively in that location. This means the soft-release technique is not necessary, according to Tuberville. Instead, the researchers will implement multiple releases in various locations to help reduce predation risk. Predators included fire ants, raccoons and dogs, with fire ants accounting for the majority of fatalities among the young tortoises.

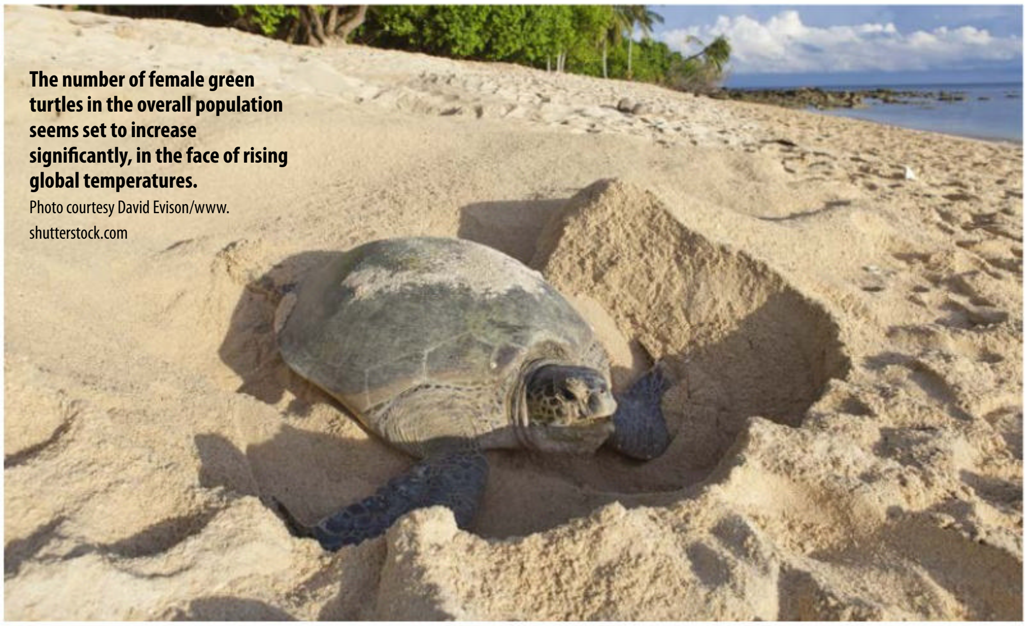
Head-starting efforts at YWMA will continue with tortoises that are 2-3 years old, an age when they are less susceptible to predators. Further research will then evaluate whether the positive effect on their post-release survival warrants the additional time that they are kept in captivity.

▲ **It is a slow process, increasing the numbers of gopher tortoises in an area, and protecting the young is a vital first step.** Photo courtesy Phil Lowe/www.shutterstock.com

Further information

Daniel P. Quinn, Kurt A. Buhlmann, John B. Jensen, Terry M. Norton, Tracey D. Tuberville. **Post-release movement and survivorship of head-started gopher tortoises.** *The Journal of Wildlife Management*, (2018) https://doi.org/10.1002/jwmg.21493

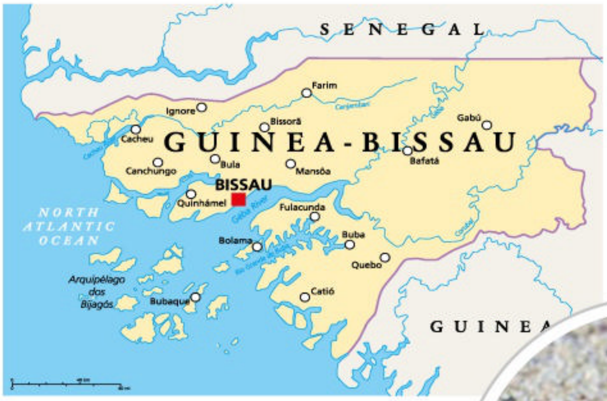
Warming temperatures threaten turtle populations



The number of female green turtles in the overall population seems set to increase significantly, in the face of rising global temperatures.
Photo courtesy David Evison/www.shutterstock.com

Up to 93% of green turtle hatchlings could be female by 2100, as climate change effectively causes feminisation of the species, new research suggests. The sex of turtle hatchlings is determined by temperature, and at present about 52% of hatching green turtles – one of seven species of sea turtle – are female.

But a study by the University of Exeter and the Marine and Environmental Sciences Centre (Portugal) shows that faced with the warmer temperatures predicted by Intergovernmental Panel on Climate Change (IPCC) scenarios, 76-93% of hatchlings would then be female. The figures are specific to the study site in Guinea-Bissau, West Africa, but researchers say they would expect a similar picture globally.



The study was carried out in the West African country of Guinea-Bissau, which is a key nesting site for green turtles, notably in the Bijagós Archipelago.
Photo courtesy Wead/www.shutterstock.com

Changing percentages

The scientists indicate that the changing gender ratio would initially lead to more females nesting, increasing the population overall, followed by a decline as incubation temperatures approach lethal levels. They also predict rising sea levels will be a further threat, submerging some 33-43% of current nesting areas used by green turtles on the beaches where the study was carried out.

"Green turtles are facing trouble in the future due to loss of nesting habitats and increasing temperatures," says Dr Rita Patricio, of the Centre for Ecology and Conservation on the University of Exeter's Penryn Campus in Cornwall. "Our results suggest the nesting population of green turtles on the Bijagós Archipelago, Guinea-Bissau, will cope with the effects of climate change until 2100.

"Cooler temperatures, both at the end of the nesting season and in shaded areas, will guarantee some hatchlings are male. Although rising temperatures will lead to more female hatchlings – and 32-64% more nesting females by 2120 – mortality in eggs will also be higher in these warmer conditions. Then as temperatures continue to rise, it may become impossible for unhatched turtles to survive."

Rising sea levels represent a further danger to marine turtles, by removing suitable nesting habitat.
Photo courtesy Damian Pankowiec/www.shutterstock.com

Running out of space

The research team, which included the Institute of Biodiversity and Protected Areas of Guinea-Bissau, say nesting sites submerged by rising seas may not simply shift inland. "Beach retreat may be feasible in some areas, but the turtles we studied were nesting on a small island, known as Poilão Island, so there is a limit as to how far the beach can go," Dr Patricio explains. "Furthermore, in other places, there may be natural barriers or human constructions that stop beaches moving inland."

As it stands, the Bijagós Archipelago is the most important nesting location for green turtles in Africa. It is also the main breeding ground for the species in the South Atlantic, making it of great importance to the future of the species here.

Increasing numbers of female green turtles are predicted to hatch in the decades ahead, because of rising temperatures.
Photo courtesy Kjersti Joergensen/www.shutterstock.com

Further information

Ana R. Patrício, Miguel R. Varela, Castro Barbosa, Annette C. Broderick, Paulo Catry, Lucy A. Hawkes, Aissa Regalla, Brendan J. Godley. **Climate change resilience of a globally important sea turtle nesting population.** *Global Change Biology*, 2018; DOI: 10.1111/gcb.14520

Lizards adapt quickly to new killer invertebrates

Some lizards in the eastern USA have adapted to invasive fire ants—which can bite, sting, and kill lizards—reversing geographical trends in behavioural and physical traits normally used to avoid predators. A new study describing this reversal reveals that new environmental challenges can override the historical influences that originally determined geographical trends in traits.

⮝ Eastern fence lizards (*Sceloporus undulatus*) have in the past increasingly relied on camouflage to avoid predators, heading southwards across their range, but the presence of invasive fire ants is now reversing this defensive mechanism.
Photo courtesy Langkilde Lab, Penn State.

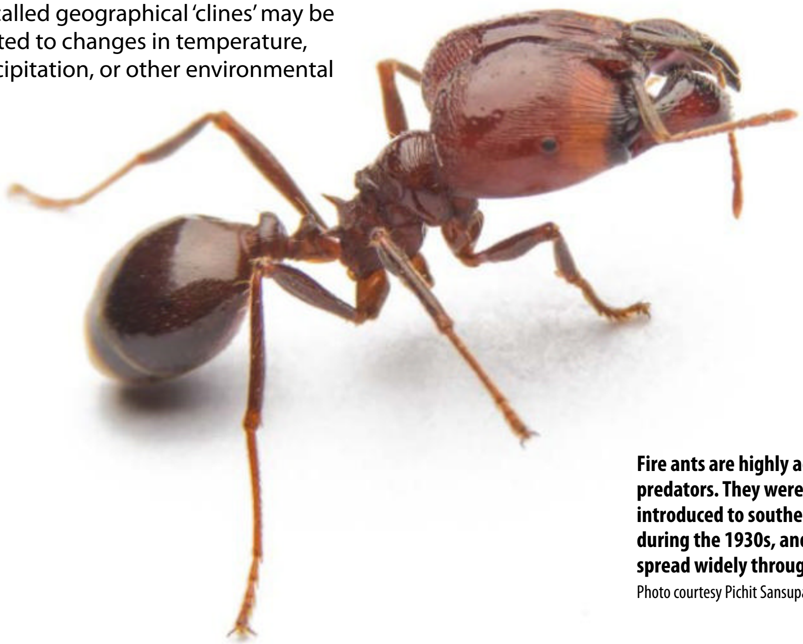
A far-reaching study

"Rapid environmental change, be it from changing climate or the introduction of invasive species, is putting a lot of pressure on native species," says Christopher Thawley, graduate student at Penn State during this study. "Usually when researchers look at how native species might respond to these new kinds of threats, they might measure one characteristic of the animal and at one or a few sites. In this study, however, we looked at three separate characteristics of eastern fence lizards from 13 sites spanning over 1600km (1000ml) and found that these lizards are capable of adapting in a concerted way to meet the threat of invasive fire ants, and in a relatively short time frame."

Some behavioural and physical characteristics within a species change gradually across geographical space. For example, animals at one end of their distribution may have relatively short limbs that, as you move across the range, become longer. These so-called geographical 'clines' may be related to changes in temperature, precipitation, or other environmental factors that also alter across their geographical range, often with latitude.

"We found that fence lizards follow predicted latitudinal clines in anti-predator behaviour where fire ants have not yet invaded—from about New Jersey to northern Tennessee," says Tracy Langkilde, professor and head of biology at Penn State. "They rely on camouflage more often at lower latitudes in the absence of fire ants."

To avoid detection by predators, lizards at lower latitudes typically sit still and use their mottled colouring to blend in with their surroundings. This is an effective strategy against most of their natural predators, like birds, which hunt visually.



Fire ants are highly aggressive predators. They were inadvertently introduced to southern parts of the USA during the 1930s, and have since spread widely through this region.
Photo courtesy Pichit Sansupa/www.shutterstock.com

Physical and behavioural changes observed

"But where fire ants are present, from central Tennessee south to coastal Alabama, that pattern reverses," explains Langkilde. "Sitting still and blending into the environment is very ineffective against fire ants, which quickly swarm and sting the lizards, paralysing and killing them. Instead, as you move southward towards the point of first invasion of fire ants, starting from Mobile in Alabama where these invaders have been around for longest, the lizards are more likely to respond as most people would when attacked by fire ants; they twitch their bodies and use their hind legs to remove fire ants and/or flee from the insects as they start to attack them. This strategy helps the lizards to survive these fire ant encounters."

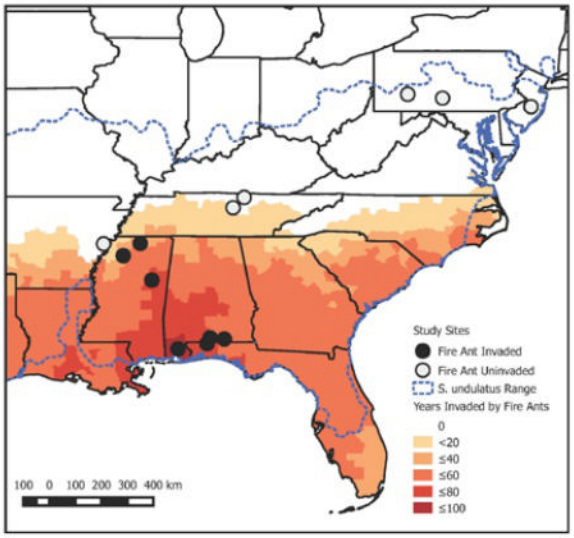
The researchers also observed a similar reversal in patterns of hind-limb length. Museum specimens of lizards collected prior to fire ant invasion—and present-day lizards at sites without fire ants—show a pattern where lizards at the southern-most sites have the shortest hind limbs. But at present day sites with fire ants, lizards at the southern-most sites have the longest hind limbs, showing a significant reversal from historical patterns. Patterns of stress physiology also shift with the presence of fire

Where invasive fire ants are present, lizards twitch and flee to remove the ants, reversing existing geographical patterns in anti-predator behaviour. Photo courtesy Langkilde Lab, Penn State.

⌃ Developing longer legs helps these lizards to escape from the fire ants. This is a male, as shown by its brighter colouration. Photo courtesy Isabel Eve/www.shutterstock.com

ants, with lizards at the southern-most sites with fire ants producing more of the stress-related hormone corticosterone when threatened.

"The documented changes to limb length and stress physiology actually help lizards deal with fire ants," explains Thawley. "Longer limbs allow for greater sprint speeds and more effective fire ant removal, and elevated corticosterone levels prime animals to perform behaviours like twitching and fleeing. So we're seeing very complex changes in these animals over a very broad geographical range. This suggests that environmental changes like invasive species can push species off their traditional trajectory for a variety of traits."



⌃ This map highlights how the ants have spread. Photo courtesy Langkilde Lab, Penn State.

Very rapid changes

While these changes might benefit lizards in the short term by allowing them to survive attack from fire ants, the costs of these changes, which seem to go against historical adaptations, are unknown. "These clines exist for a reason, so to see a complete reversal in these patterns raises a lot of questions," says Thawley. "For example, some of my previous research suggests that twitching and fleeing more frequently might make lizards more vulnerable to visual predators."

The changes observed in this study are also notable because they happened over just 80 years—about 40 lizard generations—or maybe even less. "We usually think of evolution happening over hundreds, thousands, or even millions of years so seeing that fence lizards can adapt to a threat like fire ants in such a complex way over a short time scale is interesting," adds Langkilde. "There is still a lot to learn about the broader mechanisms and consequences of adaptation to fire ants and other environmental challenges. Understanding how some species can adapt so rapidly, and the costs of doing so, will help us predict and manage our changing environment."

Further information

Christopher J. Thawley, Mark Goldy-Brown, Gail L. McCormick, Sean P. Graham, Tracy Langkilde. **Presence of an invasive species reverses latitudinal clines of multiple traits in a native species.** *Global Change Biology,* 2018; DOI: 10.1111/gcb.14510

Watch the video: https://bit.ly/2RfQfkU

The legacy of Lonesome George

Why is it that some reptiles such as tortoises live much longer than others? Greater insight into this regard has followed the death of Lonesome George in 2012. Genetic analysis of DNA from Lonesome George and samples from other giant tortoises of the Galápagos — which can live more than 100 years in captivity — found they possessed a number of gene variants linked to DNA repair, immune response, and cancer suppression not possessed by shorter-lived vertebrates.

A team of researchers drawn from Yale University in the USA, the University of Oviedo in Spain, the Galápagos Conservancy, and the Galápagos National Park Service have been following genetic clues to unravel the answers. "Lonesome George is still teaching us lessons," says Adalgisa 'Gisella' Caccone, senior researcher in Yale's Department of Ecology and Evolutionary Biology. During 2010, she began sequencing the whole genome of Lonesome George, who was the last confirmed member of the species *Chelonoidis abingdonii*, while studying the evolution of the tortoise population on the Galápagos. He is believed to have been just over a century old when he died.

Lonesome George had been discovered on the island of Pinta back in 1971, and seems to have been the last of his kind, with no other tortoises being found there since then. The vegetation on the island was destroyed by goats that had been introduced to the island, and this is regarded as the cause of the extinction of the unique tortoise population that was resident there.

Given their lifespan, it is just possible that there could be other individuals of the Pinta Island species in zoos or private collections elsewhere in the world, but after decades of searching, and a substantial reward of $10,000 offered during Lonesome George's lifetime, no further individuals of his kind have ever been traced.

Carlos Lopez-Otin at the University of Oviedo in Spain analysed the data from Lonesome George and other species of tortoises to look for gene variants associated with longevity. "We had previously described nine hallmarks of aging, and after studying 500 genes on the basis of this classification, we found interesting variants potentially affecting six of those hallmarks in giant tortoises, opening new lines for aging research," says Lopez-Otin.

⮝ Lonesome George was believed to be over a century old when he died. Photo courtesy Yale University.

➤ The tortoises on Pinta, like Lonesome George seen here, could browse on vegetation, thanks to their domed shell. Photo courtesy Arturo de Frias Marques.

⮝ Lonesome George has helped researchers to understand keys to longevity after his death. Photo courtesy Info2Learn.

Further information

Víctor Quesada, Sandra Freitas-Rodríguez, Joshua Miller, José G. Pérez-Silva, Zi-Feng Jiang *et al.*. **Giant tortoise genomes provide insights into longevity and age-related disease.** *Nature Ecology & Evolution*, 2018; DOI: 10.1038/s41559-018-0733-x

Amazing discoveries in Europe

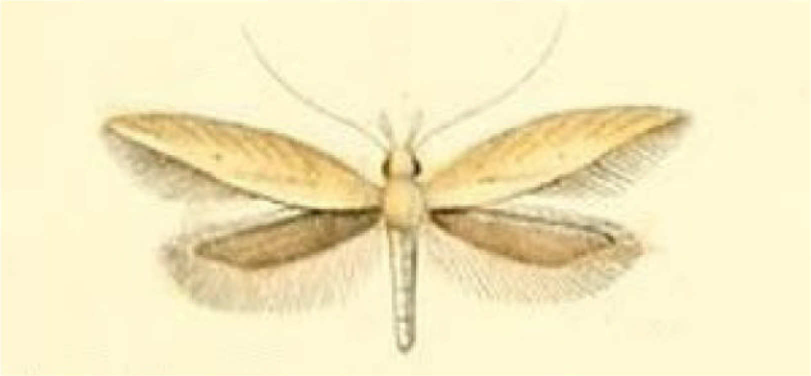
You might think that you would need to head off to a remote jungle in the hope of discovering a host of new species, but you'd be wrong! A combined Austrian-Danish research team has reported finding a staggering total of 44 new species of twirler moths - half of them within Europe! In terms of its native fauna, Europe is the best-documented continent, which makes this discovery even more incredible. The findings of this study represent the largest addition to the list of European moths in a single research article since 1887.

Totally unexpected

"The scale of newly discovered moths in one of the Earth's most studied regions is both sensational and completely unexpected," say authors Dr Peter Huemer, from the Tyrolean State Museum, and Ole Karsholt of the University of Copenhagen's Zoological Museum. To them, the new species come as proof that "despite dramatic declines in many insect populations, our fundamental investigations into species diversity are still far from complete."

For the authors, it all began when they spotted what seemed like an unclassified species of twirler moth in the South Tyrolean Alps. In order to confirm it as a new species, they conducted a five year study into the type specimens of all related species spread across the museum collections of Paris, London, Budapest and many other cities.

In order to confirm the status of all new species, the scientists not only looked for characteristic colouration, markings and anatomical features, but also used the latest DNA methods to create unique genetic fingerprints for most of the species in the form of DNA barcodes.



➤ **One of the newly discovered moths, now known to science as *Megacraspedus faunierensis*, in its natural habitat in the Alps.** Photo courtesy P. Huemer & O. Karsholt.

➤ ***Megacraspedus faunierensis* is an Alpine species.** Photo courtesy P. Huemer and O. Karsholt.

⌄ **The area – or type locality – of the new moth species *Megacraspedus faunierensis*, which lies in the Cottian Alps of Italy, near the border with France.** Photo courtesy P. Huemer & O. Karsholt.

What's in a name?

A particular challenge for the researchers was to choose as many as 44 names for the new species. Eventually, they named one of the species after the daughter of one of the authors, some after colleagues and many others after the regions associated with the particular species in question. *Megacraspedus teriolensis*, for example, effectively translates as "Tyrolean twirler moth".

Amongst the others, there is one which the scientists named *Megacraspedus feminensis* because they could only find the female, while another – *Megacraspedus pacificus*, discovered in Afghanistan – was dubbed "an ambassador of peace".

All new moths belong to the genus of large twirler moths (*Megacraspedus*) placed in the family of twirler moths (Gelechiidae), where the common name refers to their protruding modified mouthparts (known technically as labial palps).

Still more discoveries ahead!

The genus of the large twirler moths presents an especially interesting group because of their relatively short wings, with their wingspan itself ranging between 0.8-2.6cm (0.3-1in). Females are often flightless. While it remains unknown why exactly their wings are so reduced in size or absent, the scientists assume that it is most likely an adaptation to the turbulent winds at their high-elevation habitats, since the species prefer mountain areas at up to 3000m (9800ft) above sea level.

Out of the 85 documented species, however, both sexes are known in only 35 cases. The scientists suspect that many of the flightless females are hard to spot on the ground. Similarly, caterpillars of only three species have been observed to date. There is a lot more to discover, therefore, about this group of moths.

One of the few things we currently know about the large twirler moths is that all species live on different grasses. Huemer and Karsholt stress that it is of urgent importance to conduct further research into the biology of these insects, in order to identify their status and take adequate measures to ensure their future survival.

⌃ ***Megacraspedus binotella* is a species of large twirler moth first described in 1843, and widely distributed across parts of continental Europe, but in many cases, even the appearance of both sexes of such moths remains unknown.** Source PD.

Further information

Huemer P., Karsholt O. (2018) **Revision of the genus *Megacraspedus* Zeller, 1839, a challenging taxonomic tightrope of species delimitation (Lepidoptera, Gelechiidae).** ZooKeys 800: 1-278. https://doi.org/10.3897/zookeys.800.26292

Crocodiles on the move?

⮝ **The crocodiles have little opportunity of actually invading this volcanic island, and represent a particular threat to fishermen.** Photo courtesy gaborbasch/www.shutterstock.com

⮝ **It is thought that the growing crocodile population in Australia's Northern Territory is forcing these reptiles to seek out new territories.** Photo courtesy sichkarenko.com/www.shutterstock.com

Saltwater crocodiles are well-equipped to survive in the ocean, just like their marine ancestors. Photo courtesy theludi09/www.shutterstock.com

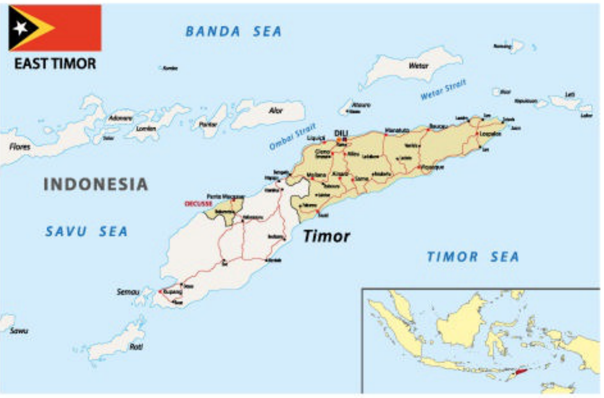
The south-east Asian island state of East Timor has an increasing problem with crocodiles, as revealed by a sharp increase in attacks on humans there. Many of these attacks were also fatal. Sebastian Brackhane, a research assistant in the Department of Remote Sensing and Landscape Information Systems of the University of Freiburg, has analysed data on crocodile attacks in relation to a rise in the population of estuarine crocodiles in East Timor.

Equipped for survival

A native of Southeast Asia and the north of Australia, saltwater crocodiles are the largest of all living crocodile species, growing to a length of up to 6m (20ft). The animals can weigh more than a ton and unlike most other species of crocodile, they can live in either fresh or salt water. This enables them to cover lengthy distances by sea.

These ancient reptiles have a strong territorial instinct and are extremely aggressive. They can attack anything that moves in the water or near the shore - including humans. After being hunted for their leather right up until the 1960s, the severely reduced population was then made a protected species in, amongst other places, Australia's Northern Territory, which lies about 450km (280ml) south of East Timor.

Previously threatened by extinction, protection of the species has now led to growth in the population. Unfortunately it has also been accompanied by a rise in crocodile attacks on humans. However, as in many other Southeast Asian and Oceanian states, there has previously been no comprehensive data on the actual number of attacks in East Timor.



⮟ **East Timor lies directly north of Australia.** Map courtesy Rainer Lesniewski/www.shutterstock.com

Obtaining data

In his field study, Brackhane spoke to local fishermen and village elders about incidents involving crocodiles, and developed a database. This showed that since East Timor became independent from Indonesia in 2002, there have been over 130 attacks - however, a high number of unreported cases must also be assumed.

"The geographic characteristics of this volcanic island mean that it only offers very limited habitat to support a larger population of crocodiles. So we wondered where all of those in East Timor had come from," says Brackhane. Surveys of workers on an oil platform in the high seas between East Timor and the Northern Territory found that saltwater crocodiles have often been sighted in the vicinity of the platform. So the researchers developed the hypothesis that the animals may migrate from Australia to East Timor.

A conservation success story!

"We believe that in many areas, the habitat in the Northern Territory has reached its maximum carrying capacity and juvenile saltwater crocodiles are now crossing the sea to East Timor to find new habitats," says Brackhane.

While the origin of the saltwater crocodiles in East Timor still has to be confirmed by a DNA analysis, he adds that it is clear many nations of Southeast Asia and Oceania are now encountering a problem with estuarine crocodiles since their stocks have recovered well thanks to conservation measures. In East Timor however, the animals receive even greater protection. There is a widely-told story that the island was created from a crocodile, so hunting "Grandfather Crocodile" is strictly prohibited.

Further information

Sebastian Brackhane, Grahame Webb, Flaminio M.E. Xavier, Marcal Gusmao, Peter Pechacek (2018). **When Conservation Becomes Dangerous: Human-Crocodile Conflict in Timor-Leste.** *The Journal of Wildlife Management*, doi: 10.1002/jwmg.21497

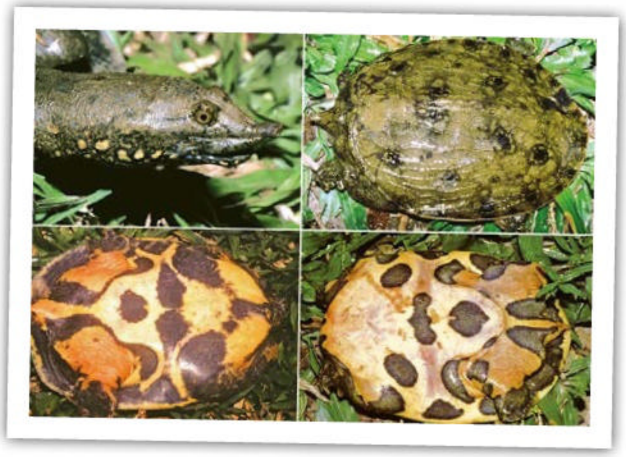
Newly-discovered turtle faces extinction

For decades, it has been assumed that Chinese softshell turtles from eastern Asia were all members of the same species - *Pelodiscus sinensis*. Widely distributed all the way from the far east of Russia through the Korean Peninsula to China and Vietnam, the species was nevertheless known to vary substantially in terms of its looks across this extensive range. Then, around the turn of the century, following a series of taxonomic debates, scientists revalidated this turtle, meaning they discovered that what was thought to have been a single species up until that stage also incorporated a total of three other separate but related species, which had previously been unrecognised.

Recently, a combined Hungarian-Vietnamese-German team of researchers has found a fifth species within the group. This particular population of turtles, previously unrecognised by science, differs both genetically and in terms of its appearance from the other four. Its most striking characteristic is the presence of well-pronounced dark blotches on the underside of its shell. The markings are also the reason why these turtles are now known under the scientific name *Pelodiscus variegatus*, with 'variegatus' translating as 'spotted' in Latin.

Conservation implications

"This particular feature, among others, helped to confirm that these individuals belong to a hitherto undescribed species," explains Professor Dr. Uwe Fritz of the Senckenberg Natural History Collections in Dresden. "Unfortunately, the splitting off of multiple species from within what used to be a single one has potentially unfortunate consequences though. While the Chinese softshell turtle was once considered to be widespread and not under any threat, each newly discovered species effectively reduces the individual numbers within the population."



⮝ The new species has a distinctly spotted appearance. Photo courtesy Thomas Ziegler.

⮝ The habitat of the newly-discovered spotted softshell turtle (*Pelodiscus variegatus*). Photo by An Vinh Ong.

"When we look at each species, the distribution range now, as well as the number of individuals making up the population, is obviously much smaller today than when they were all were combined," explains Balázs Farkas, who led the research. "Up until this stage, the newly described spotted softshell turtle was considered to be the same as the lesser Chinese softshell turtle (*Pelodiscus parviformis*), which itself was discovered by Chinese researchers in 1997."

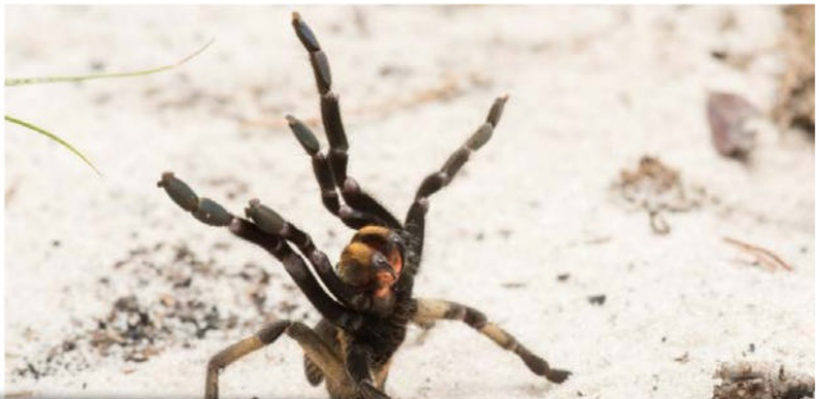
At that time, the species was already considered to be critically endangered. Now that its southern representatives have been assigned to a different species as the spotted softshell turtle, the overall population size of each species is even smaller. As a result of its restricted range and the levels of exploitation that it is subjected to, the conservation status of the new species is proposed to be critically endangered, according to the criteria laid down by the IUCN Red List of Threatened Species.

⮝ For many years, it was assumed that all Chinese soft-shell turtles belonged to one species, in spite of distinct variations in appearance across their range, as can be seen by comparing these individuals with the newly-recognised species. Photo courtesy ASMSmirMax/www.shutterstock.com & Kazakov Maksim/www.shutterstock.com

Further reading

Farkas B, Ziegler T, Pham CT, Ong AV, Fritz U (2019) **A new species of *Pelodiscus* from northeastern Indochina (Testudines, Trionychidae).** *ZooKeys* 824: 71-86. https://doi.org/10.3897/zookeys.824.31376

New tarantula species from Angola has a one–of–a–kind 'horn' on its back



➤ **An individual of the newly-described species assuming a defensive posture in its natural habitat.** Photo courtesy Kostadine Luchansky.

ANGOLA
ZAMBIA
TANZANIA
NAMIBIA
BOTSWANA
MOZAMBIQUE
LUANDA
NTIC

Map courtesy crazystocker/www.shutterstock.com

A new species of tarantula with a bizarre horn-like protuberance sticking out of its back was recently discovered in Angola - a largely underexplored country located at the intersection of several Afrotropical ecoregions in the southwest of the continent.

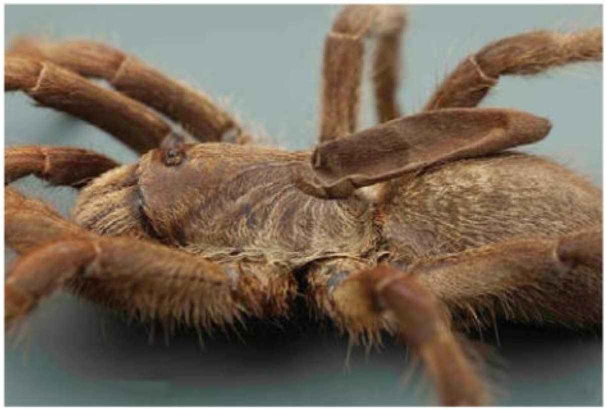
Collected as part of the National Geographic Okavango Wilderness Project, which aims to uncover the undersampled biodiversity in the entire Okavango catchment of Angola, Namibia and Botswana, thereby paving the way for sustainable conservation in the area, the new arachnid has been described by Dr John Midgley and Dr Ian Engelbrecht.

Although the new spider (*Ceratogyrus attonitifer* sp.n.) belongs to a group known as horned baboon spiders, the peculiar protuberance is not present in all of these species. Moreover, in the other species – where it is present – the structure is completely sclerotised and therefore hard, whereas the Angolan specimens have a soft and characteristically longer 'horn'. At present, the function of this curious structure remains unknown.

This new spider's extraordinary appearance has also given rise to its scientific name, which is *C. attonitifer*. This derives from the Latin root *attonit–* (meaning 'astonishment' or 'fascination'), while the suffix *–fer* literally translates as 'bearer of' or 'carrier'. This name was chosen to reflect the astonishment of the authors on the discovery of such a remarkable species. "No other spider in the world possesses a similar foveal protuberance," say the scientists.

During a series of surveys between 2015 and 2016, the researchers collected several female specimens from the miombo forests of central Angola. To find them, the team would normally spend the day locating burrows, often hidden among grass tufts, but sometimes present in open sand. They would then excavate the spiders during the night. Interestingly, whenever the researchers placed an object in the burrow, the spiders were quick and eager to attack it, facilitating this process.

⮟ **The newly-described baboon spider species (*Ceratogyrus attonitifer*), showing the peculiar soft and elongated horn-like protuberance sticking out of its back.** Photo courtesy Dr Ian Enelbrecht.



Local insights

The indigenous people in the region provided additional information about the biology and lifestyle of this baboon spider. While undescribed in the scientific literature until very recently, the arachnid has long been known under the name of "chandachuly" among the local tribes.Thanks to their reports, information about the animal's behaviour could also be noted.

The tarantula tends to prey on insects and the females can be seen enlarging already existing burrows rather than digging their own. Also, the venom of the newly described species is said not to be dangerous to humans, even though there have been some fatalities caused by infected bites left untreated because of poor medical access.

Much more to discover

In conclusion, the researchers note that the discovery of this distinctive baboon spider from Angola not only substantially extends the known distributional range of the genus, but it also serves as further evidence of the hugely unreported endemic fauna of the country.

"The general lack of biodiversity data for Angola is clearly illustrated by this example, highlighting the importance of collecting specimens in biodiversity frontiers," they explain. Indeed, apart from this newly-described species, the survey produced specimens of two other potentially unrecorded spiders and range expansions for other genera. Unfortunately at present however, the available material is currently insufficient to identify and describe these with absolute certainty, and further field investigations will be required.

Further information

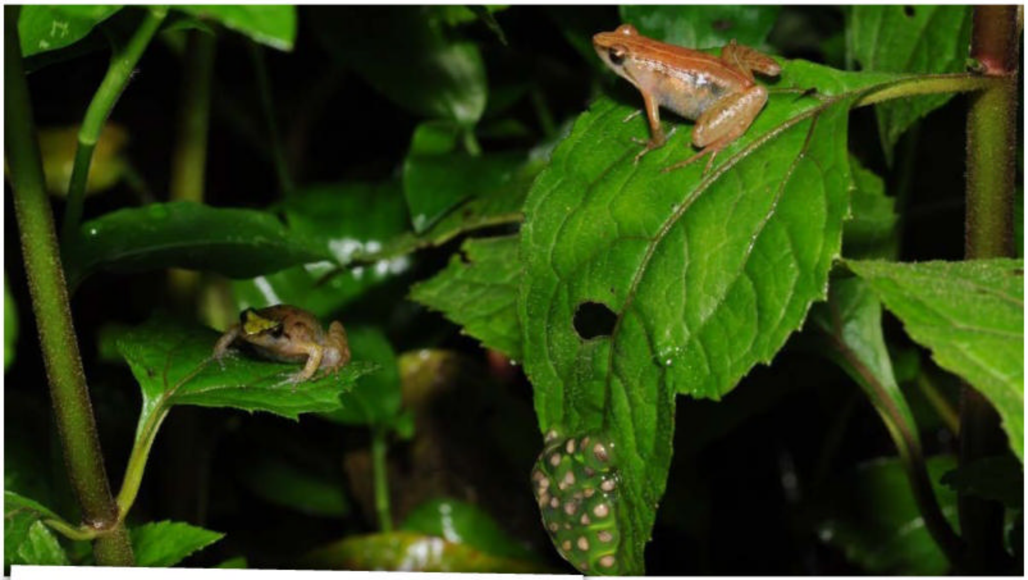
Midgley JM, Engelbrecht I (2019) **New collection records for Theraphosidae (Araneae, Mygalomorphae) in Angola, with the description of a remarkable new species of *Ceratogyrus*.** *African Invertebrates* 60(1): 1-13. https://doi.org/10.3897/afrinvertebr.60.32141

New Ethiopian species of puddle frog found on an unexplored mountain

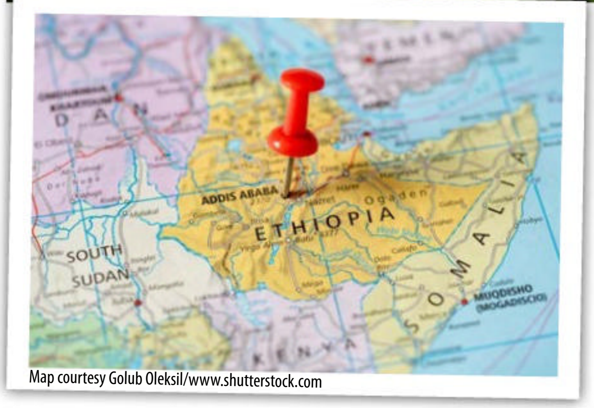
A previously unknown species of puddle frog has just been discovered by New York University (NYU) Abu Dhabi researchers at the unexplored and isolated Bibita Mountain in southwestern Ethiopia. The research team named the new species scientifically as *Phrynobatrachus bibita* sp. nov., with its common name now being the Bibita Mountain dwarf puddle frog, reflecting its range.

NYU Abu Dhabi postdoctoral associates Sandra Goutte and Jacobo Reyes-Velasco were exploring this isolated mountain where some of Ethiopia's last primary forest remains. Bibita Mountain has been attracting interest from the team for several years, thanks to its isolation and the fact that it had not been visited by any other zoologists before.

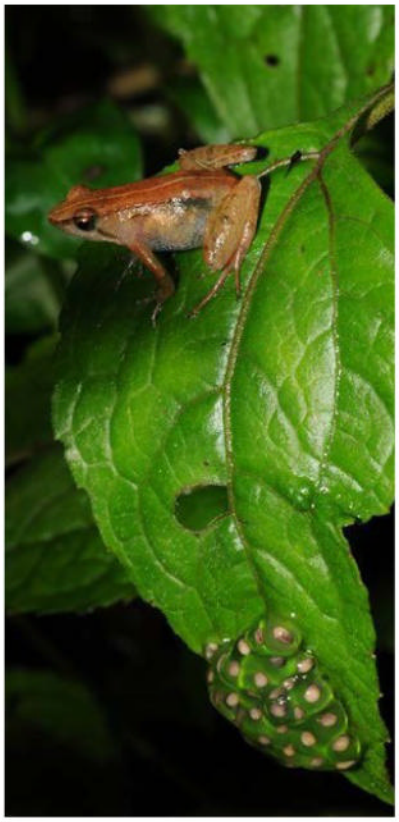
"Untouched, isolated, and unexplored: it had all the elements to spike our interest," admits Dr. Reyes-Velasco, who initiated the expedition to explore this unknown area, adding: "We tried to reach Bibita during a previous expedition in 2016 without success. Last summer, we used a different route that brought us to higher elevation."



Two females and eggs of the newly-described species (*Phrynobatrachus bibita*).
Photo courtesy S. Goutte and J. Reyes-Velasco.



Map courtesy Golub Oleksil/www.shutterstock.com



A female Bibita Mountain puddle frog next to egg clutches.
Photo by S. Goutte and J. Reyes-Velasco.

A distinctive appearance

The team's studies have revealed that the new, tiny frog is unique among Ethiopian puddle frogs, partly because of its size. Males measure just 17mm (0.7in) overall, while females are only slightly larger at 20 mm (0.8in). Among other morphological features, a slender body with long legs, elongated fingers and toes, and a golden colouration set this frog apart from its closest relatives.

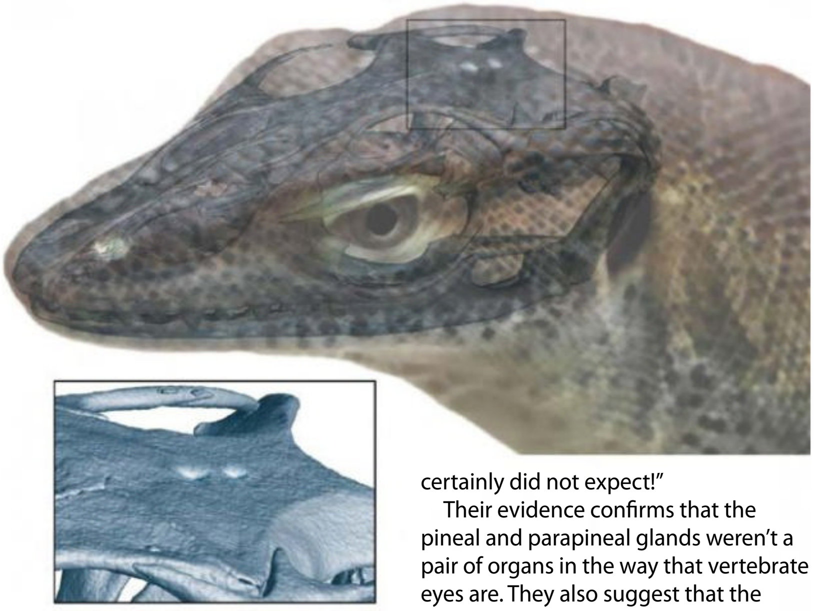
"When we looked at the frogs, it was obvious that we had found a new species. These frogs look so different from any Ethiopian species we had ever seen before!" explains Dr. Goutte. Back in NYU Abu Dhabi, the research team sequenced tissue samples from the new amphibian and discovered that *Phrynobatrachus bibita* sp. nov. is genetically different from any other frog occurring in the region.

"The discovery of such a genetically distinct species within only a couple of days of being on the mountain is the perfect demonstration of how important it is to assess the biodiversity of these types of places," adds NYU Abu Dhabi Program Head of Biology Stéphane Boissinot, who has been working on Ethiopian frogs since 2010. "The Bibita Mountain probably has many more unknown species that await discovery; it is essential for biologists to find them, in order to protect them and their habitat properly."

Further reading

Goutte S, Reyes-Velasco J, Boissinot S (2018) **A new species of puddle frog from an unexplored mountain in southwestern Ethiopia (Anura, Phrynobatrachidae, *Phrynobatrachus*).** *ZooKeys* 824: 53–70. https://doi.org/10.3897/zookeys.824.31570

A FOUR–EYED LIZARD



➤ This image depicts a reconstruction of what the extinct monitor lizard might have looked like. The parietal and pineal openings are visible here on the overlaid skull. Reconstruction courtesy Senckenberg Gesellschaft für Naturforschung / Andreas Lachmann / Digimorph.org

Researchers have evidence that an extinct species of monitor lizard had four eyes, a first among known jawed vertebrates. Today, only the jawless lampreys (a type of primitive fish) have four eyes.

The third and fourth eyes refer to pineal and parapineal organs, which are eye-like photosensory structures that responding to light and are located on the top of the head. They play key roles in orientation and in circadian (24 hour) and annual life cycles. The new findings help to explain the evolutionary history of these structures among vertebrates.

The photosensitive pineal organ is found in a number of lower vertebrates such as fishes and frogs. It is often referred to as the 'third eye' and was widespread in primitive vertebrates.

"On the one hand, there was this idea that the third eye was simply reduced independently in many different vertebrate groups such as mammals and birds and is retained only in lizards among fully land-dwelling vertebrates," says Krister Smith at the Senckenberg Research Institute in Germany. "On the other hand, there was a theory that the lizard third eye developed from a different organ, called the parapineal, which is well-developed in lampreys. These two ideas aren't really compatible.

A unique find

"By discovering a four-eyed lizard, in which both pineal and parapineal organs formed an eye on the top of the head, we can confirm that the lizard third eye really is different from the third eye of other jawed vertebrates," Smith continues.

Smith and his colleagues got the idea that the fossilised lizards might have a fourth eye after other experts came to contradictory conclusions about where the lizard's third eye was located.

Smith says that the first question to explore the strange idea of a lizard with four eyes was whether this unusual feature occurred in more than one individual of the same age?

⮝ We think of eyes as a means of obtaining visual insights in the world around us, but the additional third eye provides a different view of the world, serving more as a monitor of physical changes in the environment.
Photo courtesy mountainpix/ www.shutterstock.com

The additional 'eye' in the centre of the lamprey's forehead can be seen here.
Photo courtesy Andrei Nekrassov/www.shutterstock.com

The team turned to museum specimens collected nearly 150 years ago at Grizzly Buttes as part of the Yale College Expedition to the Bridger Basin, in the US state of Wyoming. And, it turned out that the answer to their question was yes! CT scans showed that two different individuals had spaces where a fourth eye would have been, which, Smith admits: "I certainly did not expect!"

Their evidence confirms that the pineal and parapineal glands weren't a pair of organs in the way that vertebrate eyes are. They also suggest that the third eye of lizards evolved independently of the third eye in other vertebrate groups.

The hidden value of museum collections

Smith says that while there's nothing mystical about the pineal and parapineal organs, they do confer extraordinary abilities. For instance, they allow some lower vertebrates to sense the polarisation of light and use that information to orient themselves geographically.

Scientists still have a lot to learn about the evolution of these organs and their functions in living animals, according to the researchers. The new findings are a reminder of the hidden value that can be present within fossils that have been left lying around in museums for more than a century.

"The fossils that we studied were collected in 1871, and they are quite scrappy - really not in good shape," Smith acknowledges. "You would be forgiven for looking at them and thinking that they must be useless. However, our work shows that even small, fragmentary fossils can be enormously useful."

Further information

Smith *et al*. (2019) **The Only Known Jawed Vertebrate with Four Eyes and the Bauplan of the Pineal Complex**. *Cell Biology* DOI:https://doi.org/10.1016/j.cub.2018.02.021

New stiletto snake discovered

Following a series of recent surveys in west Africa, in the area of north-western Liberia and south-eastern Guinea, an international team of researchers found three stiletto snakes, which have now been identified as a species previously unknown to science. It has been named as *Atractaspis branchi*, or Branch's stiletto snake, in honour of the recently deceased South African herpetologist Prof. William Roy (Bill) Branch, who was a world expert on African reptiles.

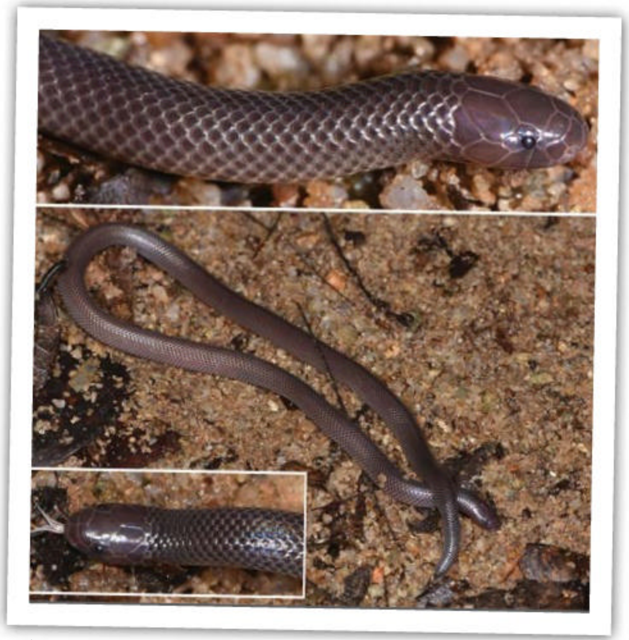
The discovery, made by a team headed by Dr Mark-Oliver Roedel from the Natural History Museum, Berlin, provides further evidence for the status of the western part of the Upper Guinea forest zone as a very important centre of endemic biodiversity, being home to species found nowhere else on earth.

Stiletto snakes are characterised by their unusual skulls and venom delivery system, which allows them to attack and stab sideways using a fang sticking out of the corner of their mouths. While most of these burrowing snakes are not venomous enough to kill a human - even though some are able to cause serious localised tissue necrosis (death) - this behaviour makes them impossible to handle using the standard approach of restraining them with fingers behind the head. In fact, they can even stab with their mouths closed!

Habitat

This new species lives in primary rainforest and on the edges of rainforest in the western region of the forests present in Upper Guinea. Branch's stiletto snake is most likely endemic to this area, which is unfortunately a threatened biogeographic region, in spite of being recognised for its unique and diverse fauna.

The first specimen of the new species was collected at night from a steep bank of a small rocky creek in a lowland evergreen rainforest in Liberia. When it was lifted up, the snake tried to hide its head under body loops, bending it at an almost right angle, so that its fangs were partly visible on the sides. Then it repeatedly struck out. It is also reported to have jumped distances almost as long as its entire body. The other two specimens used for the description of the species were collected from banana, manioc and coffee plantations in south-eastern Guinea, about 27km (17ml) apart.

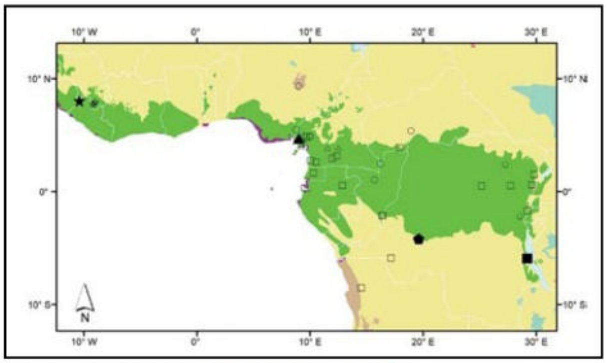


▲ **A close-up view of the first specimen of the newly-described species of stiletto snake in its natural habitat.**

Photo courtesy Mark-Oliver Roedel.

"The discovery of a new and presumably endemic species of fossorial or burrowing snake from the western Upper Guinea forests is not very surprising," says Dr Roedel. "However, further surveys are needed to resolve the range of this new species of snake, and to gather more information about its ecological needs and biological features."

The map to the left reveals how the new species fits in alongside the related mole viper (*A. reticulata*). Records are based on museum specimens, literature and database (GBIF) records, with large closed symbols representing the type localities of the different taxa. Stars have been used to indicate Branch's stiletto snake and circles to indicate mole vipers. Triangles reveal localities where the subspecies *A. r. reticulata* has been documented; quadrats have been used for *A. r. heterochilus*; and diamonds for *A. r. brieni*. Country borders are indicted as white lines and major biomes are based on Olson *et al.* (2001).



▲ Map courtesy Mark-Oliver Roedel.

◀ **The southern stiletto snake (*Atractaspis bibronii*) is a widely-distributed member of this group of snakes, ranging over southern parts of Africa. Until these new discoveries were made, the genus was believed to be comprised of just 15 species.**

Photo courtesy Christopher Reusch/www.shutterstock.com

Further reading

Mark-Oliver Rödel, Christoph Kucharzewski, Kristin Mahlow, Laurent Chirio, Olivier Pauwels, Piero Carlino, Gordon Sambolah, Julian Glos. **A new stiletto snake (Lamprophiidae, Atractaspidinae, *Atractaspis*) from Liberia and Guinea, West Africa.** *Zoosystematics and Evolution*, 2019; 95 (1): 107 DOI: 10.3897/zse.95.31488

BEES ADDING UP

Researchers have found bees can do basic mathematics, in a discovery that expands our understanding of the relationship between brain size and brain power. Building on their finding that honeybees can understand the concept of zero, Australian and French researchers then set out to test whether bees could perform arithmetic operations like addition and subtraction.

Solving maths problems requires a sophisticated level of cognition, involving the complex mental management of numbers, long-term rules and short term working memory. The revelation that even the miniature brain of a honeybee can grasp basic mathematical operations is not just fascinating, but has obvious implications for the future development of artificial intelligence (AI), particularly in improving rapid learning.

Illustration by Sashkin/www.shutterstock.com

Honeybees can be taught to carry out mathematical tasks. Photo courtesy Daniel Prudek/www.shutterstock.com

Two separate abilities required

Led by researchers from RMIT University in Melbourne, Australia, the new study showed bees can be taught to recognise colours as symbolic representations for addition and subtraction, and that they can use this information to solve arithmetical problems. RMIT's Associate Professor Adrian Dyer says that numerical operations like addition and subtraction are complex because they require two levels of processing.

"You need to be able to hold the rules around adding and subtracting in your long-term memory, while mentally manipulating a set of given numbers in your short-term memory," Dyer explains.

"On top of this, our bees also used their short-term memories to solve arithmetical problems, as they learned to recognise plus or minus as abstract concepts rather than being given visual aids.

"Our findings suggest that advanced numerical cognition may be found much more widely in nature among non-human animals than previously suspected. The exciting thing is that if maths doesn't require a massive brain, there might also be new ways for us to incorporate interactions of both

Bees are already known to have complex methods of communication, with workers being able to indicate the location of flowering plants to their companions, maximising opportunities to forage effectively. Photo courtesy RUKSUTAKARN studio/www.shutterstock.com

long-term rules and working memory into designs to improve rapid AI learning of new problems."

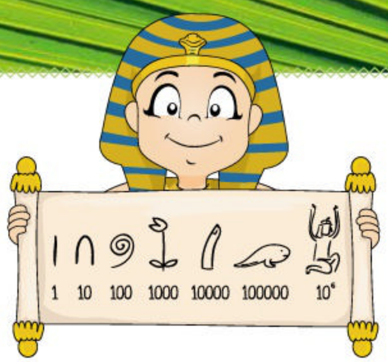
There is considerable debate around whether animals know or can learn complex number skills. Many species can understand the difference between quantities and use this to forage, make decisions and solve problems. But numerical cognition, such as exact number and arithmetical operations, requires a more sophisticated level of processing. Previous studies have shown some primates, birds, babies and even spiders can add and/or subtract. The new research adds bees to that list.

A school for bees

The experiment, conducted by PhD researcher Scarlett Howard in the Bio Inspired Digital Sensing-Lab (BIDS-Lab) at RMIT, involved training individual honeybees to visit a Y-shaped maze.

The bees received a reward of sugar water when they made a correct choice in the maze, and received a bitter-tasting quinine solution if the choice was incorrect.

Honeybees will go back to a place if the location provides a good source of food, so the bees returned repeatedly to the experimental set-up to collect nutrition and continued to learn. When one of the bees flew into the entrance of the maze, they would see a set of elements, numbering between 1-5 shapes. The shapes were either blue, indicating that the bee had to add, or yellow, which meant the bee needed to subtract.

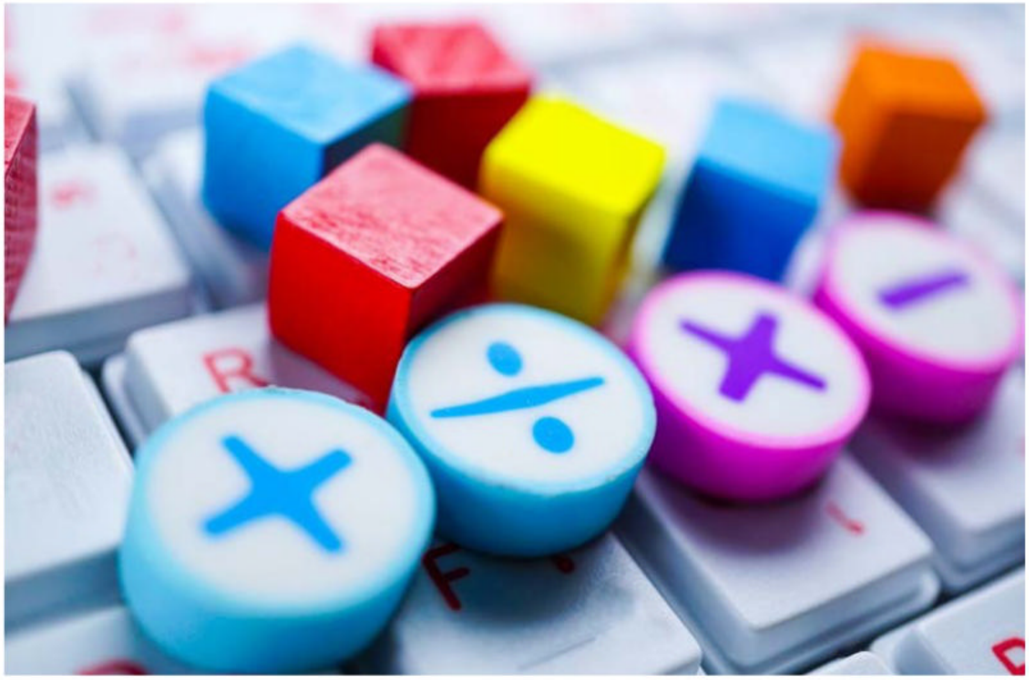


The ancient Egyptians used symbols corresponding to numbers. In this case, the researchers used colours to communicate with the bees. Graphic Lorelyn Medina/www.shutterstock.com

After viewing the initial number, the bee would fly through a hole into a decision chamber where it could choose to fly to the left or right side of the maze. One side had an incorrect solution to the problem and the other side had the correct solution of either plus or minus one. The correct answer was changed randomly throughout the experiment to avoid bees learning to visit just one side of the maze.

At the beginning of the experiment, the bees made random choices until they could work out how to solve the problem. Eventually, over 100 learning trials that took 4-7 hours, bees learned that blue meant +1, while yellow corresponded to -1. The insects could then apply the rules to new numbers.

Scarlett Howard explains that the ability to do basic maths has been vital in the flourishing of human societies historically, with evidence that the Egyptians and Babylonians were using arithmetic around 2000BC. "These days, we learn as children that a plus symbol means you need to add two or more quantities, while a minus symbol indicates you subtract," she says. "Our findings reveal that the complex understanding of mathematical symbols as a language is something that many brains can probably achieve, and also helps to explain how many human cultures independently developed numeracy skills."



Colours were used for training purposes, indicating whether the bee needed to add or subtract. Photo courtesy sadiron pamai/www.shutterstock.com

Further information

Scarlett R. Howard, Aurore Avarguès-Weber, Jair E. Garcia, Andrew D. Greentree, Adrian G. Dyer. **Numerical cognition in honeybees enables addition and subtraction.** *Science Advances*, 2019; 5 (2): eaav0961 DOI: 10.1126/sciadv.aav0961

Why are some snake venoms more deadly?

A n international study involving scientists from the National University of Ireland, Galway, The University of St Andrews, Trinity College Dublin and the Zoological Society of London has helped to give a better understanding of why the venom of some snakes makes them so much deadlier than others.

Snakes are infamous for possessing potent venoms, a fact that makes them formidable predators and also strikes fear into humans and other animals alike. However, some species, such as cobras, boomslangs and rattlesnakes have far more venom than they apparently need—in a single reserve of venom, they may have the potential to kill thousands of individual prey animals and several adult humans.

But not all venomous snakes are so dangerous. For example, the marbled sea snake (*Aipysurus eydouxii*) has only a tiny amount of very weak venom, making it effectively harmless to any relatively large animals such as humans. Why venoms vary so much in their ability to kill or incapacitate potential prey animals has long puzzled scientists, with several competing hypotheses suggested as explanations.

⮝ **A Mozambique spitting cobra (*Naja mossambica*) releasing its deadly venom.** Photo courtesy Stuart G Porter/www.shutterstock.com

A reflection of their prey

This new study tackled this question by comparing records of venom potency and quantity for over 100 venomous snake species, ranging from rattlesnakes, cobras and the tree dwelling boomslangs of Africa to sea snakes and burrowing asps. The team found strong evidence that venoms have evolved to be more potent against animals that are closely related to the species that the snake

A rattlesnake with drops of its exceedingly potent venom visible at the tips of its fangs. Photo courtesy Maria Dryfhout/www.shutterstock.com

A sea snake, in the form of a banded sea krait - lying in ambush for fish on a reef in the Philippines. The venom that snakes produce is targeted to work most effectively on their prey, according to this new research. Photo courtesy Oksana Golubeva/www.shutterstock.com

commonly eats.

Dr Kevin Healy, who conducted the research at the University of St Andrews and is now Lecturer of Zoology at the National University of Ireland, Galway, comments: "These results make sense from an evolutionary viewpoint as we expect that evolution will have shaped venoms to be more efficient at killing the prey animals that are most often the target of the venom. You won't find many mice in the sea so we wouldn't expect a sea snake to have evolved a venom that is more effective at killing mice than fish."

It is now clear that some chemical constituents in snake venom can be helpful, in the development of new drugs to treat medical conditions. Photo courtesy Joe McDonald/ www.shutterstock.com

Links to hunting opportunities

The research also showed that the amount of venom a snake has will depend both on its size and the environment where it occurs. "Like all substances, venom is dosage-dependent," explains fellow researcher Dr Andrew Jackson, Associate Professor in Zoology at Trinity College, Dublin. "Even alcohol, coffee and water can be toxic at high enough volumes so we needed to consider how much venom is produced by different species of snake and stored in their venom glands.

"We found that big terrestrial species produce the most venom, while smaller tree dwelling or aquatic species had the least. This difference may be related to how often a snake encounters its prey in these different environments, with terrestrial species requiring a larger reserve of venom to take advantage of the rarer opportunities to feed."

Predictions of potency

The results of the study also have potential to aid in our understanding when it comes to human cases of snakebite. "These are a major health issue worldwide, with 2.7 million people being affected each year," says Dr Chris Carbone of the Institute of Zoology in the Zoological Society of London. "Appreciating how venom evolves may help us better identify the risks to humans from different snake groups, and also potentially from other venomous animals such as spiders, scorpions, centipedes and jellyfish."

The approach used in the study may also help researchers to predict the potency of venoms in species that have yet to be tested, and even pinpoint potentially useful healthcare-related applications. Dr Healy concludes: "The next step is to see how well our model may assist in a predictive sense. Also, by using ecological and evolutionary data for available species, we may be able to use our approach as a tool to identify other species which could have properties in their venoms that are useful for biomedical purposes, such as drug development."

Snakes that are primarily arboreal produce less venom than those living at ground level. This is a blue viper (*Trimeresurus insularis*), a species of pit viper found in Indonesia and East Timor. Photo courtesy DedeDian/ www.shutterstock.com

Further reading

Kevin Healy, Chris Carbone, Andrew L. Jackson. **Snake venom potency and yield are associated with prey-evolution, predator metabolism and habitat structure.** *Ecology Letters*, 2019; DOI: http://dx.doi.org/10.1111/ele.13216

World's biggest bee rediscovered

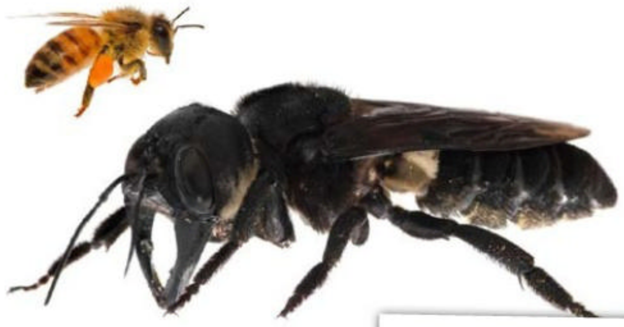
Last seen in 1981 and thought lost to science, a team of scientists and conservationists has recently rediscovered Wallace's giant bee (*Megachile pluto*), which, as its name suggests, is the world's largest bee. The insect was found in the forests of an Indonesian island, with its name commemorating that of Alfred Russell Wallace, the famous Victorian explorer and naturalist.

Wallace, a British entomologist, discovered the giant bee while exploring the Indonesian island of Bacan. He described the female bee, which is about the length of a human thumb, as "a large black wasp-like insect, with immense jaws like a stag-beetle".

The bee was not recorded again until 1981, when entomologist Adam Messer rediscovered it on three Indonesian islands and was able to observe some of its behaviour, including how it uses its mandibles to gather resin and wood for its nests. Since then, other teams have looked for the bee, with no luck until now, although two of these incredibly rare insects were listed as mounted specimens on the eBay auction site in 2018. Both of these individuals are believed to have originated from the Maluku Islands (also referred to as the Moluccas), coming from the islands of Bacan and Halmahera.

The most recent encounter

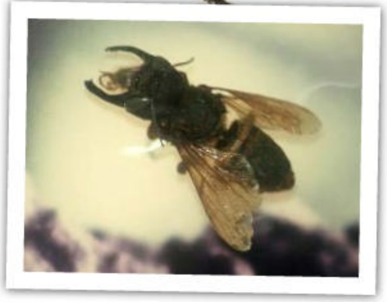
The latest search also located Wallace's giant bee in this group of Indonesian islands, but the exact location is being kept secret, to protect the population there. The discovery does, however, rekindle hope that more of the region's forests still harbour this very rare species. The giant bee has a wingspan that exceeds 6cm (2.5in), but despite its conspicuous size, it has been unrecorded by scientists for nearly 40 years.



➤ A composite image showing the scale of Wallace's giant bee set alongside a typical honeybee. Image © Clay Bolt/claybolt.com

▲ Alfred Russell Wallace, who first found the bee in 1858 - about two years before this photo was taken in Singapore. He travelled widely through Indonesia, and collected a number of previously unknown species.

▼ Dr Simon Robson with a live Wallace's giant bee in Indonesia. Photo courtesy Clay Bolt.



▲ The female bee's characteristically large mandibles are very evident here. Photo courtesy Stavenn/CC BY-SA 3.0.

Dr Simon Robson and Dr Glen Chilton, an honorary professor at Saint Mary's University in Canada, joined with Eli Wyman from Princeton University and Clay Bolt, a conservation photographer from Montana, in a quest to find this bee. The team was supported by Global Wildlife Conservation, an organisation based in Austin, Texas that runs a Search for Lost Species programme.

"It was absolutely breathtaking to see this 'flying bulldog' of an insect that we weren't sure existed anymore," says Clay Bolt, a natural history photographer specialising in bees, who took the first photos and video of the species alive. Clay had spent years researching the right habitat where the bee was most likely to be found, with his collaborator and fellow team member Eli Wyman from Princeton University.

"To see how beautiful and big the species is in real life, to hear the sound of its giant wings thrumming as it flew past my head, was just incredible. My dream is to now use this rediscovery to elevate this bee to a symbol of conservation in this part of Indonesia," adds Clay.

Nesting habits

The female giant bee makes her nest in active arboreal termite mounds, using her large mandibles to collect sticky tree resin to line the nest and protect it from invading termites. In hot and humid conditions, and sometimes during torrential downpours, the team observed dozens of termite mounds over the course of the search.

It wasn't until the last day of a five-day stop in an area of interest that the team found a single female Wallace's giant bee living in an arboreal termites' nest in a tree about 2.5m (8.25ft) off the ground. Females are about a third bigger than males, growing to about 3.8cm (1.5in) in length.

"Messer's rediscovery gave us some insight, but we still know next to nothing about this extraordinary insect," says Eli Wyman. "I hope this rediscovery will spark research that will give us a deeper understanding of this unique bee and inform any future efforts to protect it from extinction."

Looking ahead

Although little is known about the bee, the species depends on primary lowland forest for resin and the nests of tree-dwelling termites, as was confirmed during this study. In Indonesia, forest destruction for agriculture, however, threatens the habitat for this species and many others as well. Between 2001 and 2017, Indonesia lost 15 percent of its tree cover, according to Global Forest Watch.

The team has already started conversations with Indonesian collaborators to look for Wallace's giant bee in other locations – with the hope of eventually working together to develop a plan to strengthen conservation measures for the bee. Meanwhile, a documentary film, entitled *In Search of the Giant Bee*, is now being produced by Vanessa Dylyn of Matter of Fact Media, in association with Glen Chilton.

Watch the video!

https://www.youtube.com/watch?time_continue=5&v=JT_B6sSuF5I

Spiders and Star Wars

Despite being widely distributed across northern and central parts of South America, bald-legged spiders had never been confirmed in Colombia until the recent study by the team of Drs Carlos Perafan and Fernando Perez-Miles (based at the Universidad de la Republica, Uruguay) and William Galvis (from the Universidad Nacional de Colombia). Now however, they have confirmed the presence of six previously unknown species inhabiting the country.

Four of these newly-documented spiders (family Paratropididae) did not fit into any existing genus. As a result, the scientists had to create a brand new one for them, which they called *Stormtropis* in reference to the Star Wars' clone trooper army known as stormtroopers.

A bald-legged spider of the genus *Paratropis* in its natural habitat. Photo courtesy Carlos Perafan.

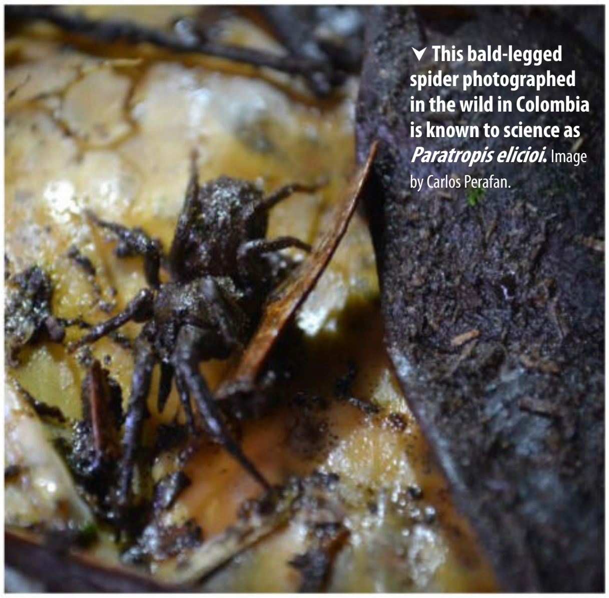
This group of spiders coat themselves with particles of soil to assist their camouflage. The group range widely, occurring in Central America too, with this particular species - *Paratropis tuxtlensis* - being found in Mexico. Photo courtesy Jorge I. Mendosa/CC BY-SA 4.0.

Interesting associations

Ranking amongst the lesser-known members of the group known as mygalomorphs, which includes tarantulas, the bald-legged spiders are a family comprised of only 11 small- to medium-sized species, which look very similar to each other, and whose links have long been a matter of debate. In fact, it is due to their almost identical appearance and camouflage skills that led to the new bald-legged spider genus being linked with the fictional stormtroopers.

One of the most striking abilities of the bald-legged spiders is their ability to stick soil particles to their cuticle, which allows them to be camouflaged by the environment. "The stormtroopers are the soldiers of the main ground force of the Galactic Empire. These soldiers are very similar to each other, with some capacity for camouflage, but with unskillful movements, just like this new group of spiders!" explains Dr Perafan.

"We wanted to make a play on words with the name of the known genus, *Paratropis*, and of course, we also wanted to pay tribute to one of the greatest sagas of all time," adds his colleague, Fernando Perez-Miles.



This bald-legged spider photographed in the wild in Colombia is known to science as *Paratropis elicioi*. Image by Carlos Perafan.

An altitudinal record

One of the new 'stormtrooper' species (which has been named *Stormtropis muisca*) has also been found at a higher altitude in Colombia than any other member of the family. It was recorded from an elevation of at least 3,400m (11,155ft) in the central Andes. However, the authors note that they have evidence of species living above 4,000m (13,125ft) and this is something they will be returning to in a future paper.

In the course of their fieldwork, the researchers also confirmed previous assumptions that bald-legged spiders are well adapted to running across the ground's surface. The spiders were seen to stick soil particles to their scaly backs as a means of camouflage against predators. More interestingly, perhaps, the team records several cases of various bald-legged species burrowing into ravine walls or soil – a type of behaviour that had not been reported up until that point. Their suggestion is that it might be a secondary adaptation, so that the spiders could exploit additional habitats.

In conclusion, not only did bald-legged spiders turn out to be present in Colombia, but they also seem to be pretty abundant there. Following the present study, representatives of three genera (*Anisaspis*, *Paratropis* and *Stormtropis*) are currently known to exist in the country.

A close-up photograph of one of the new bald-legged spider species found in Colombia: this is *Stormtropis muisca*, which also holds the highest altitudinal record for any member of the family. Photo courtesy Carlos Perafan.

Further information

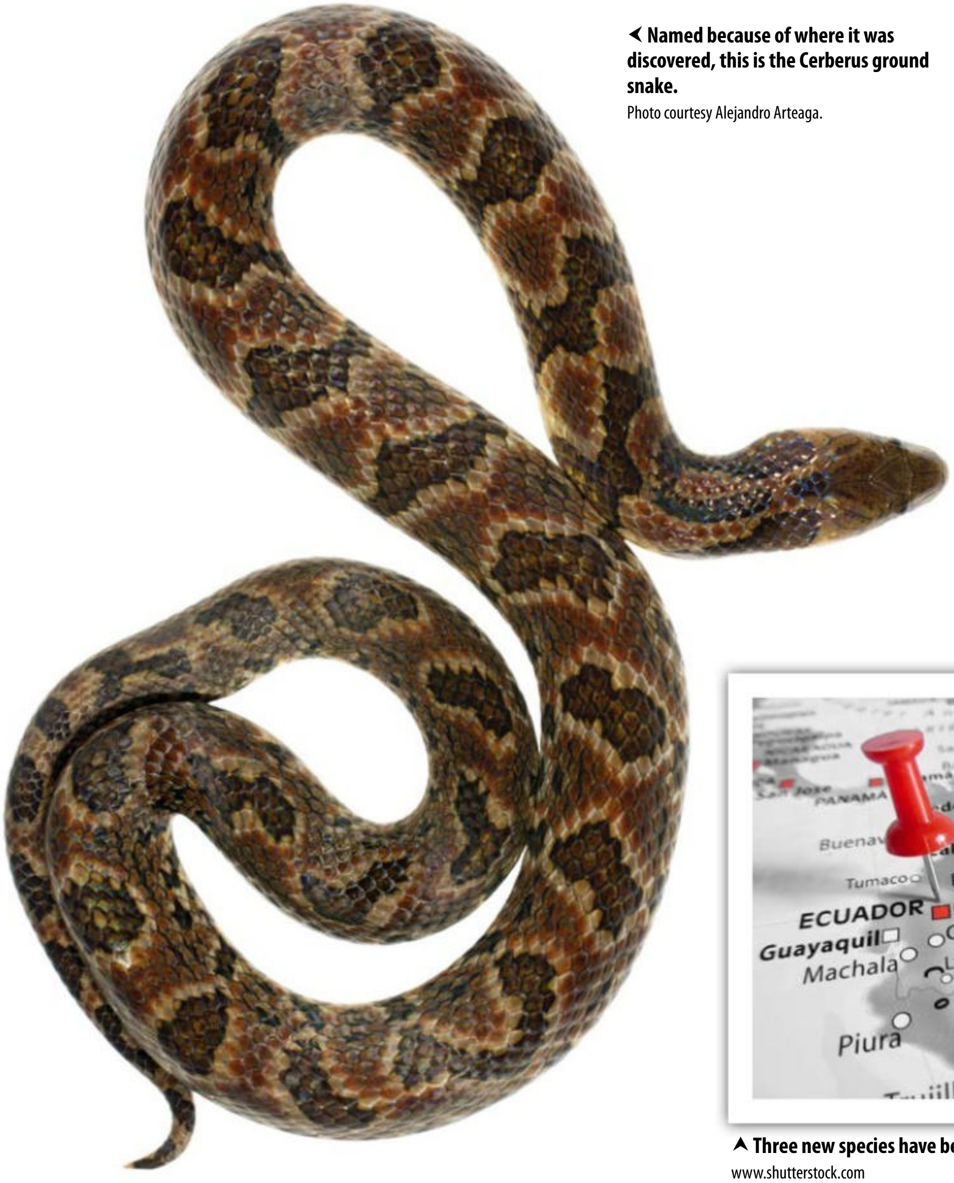
Perafan C, Galvis W, Perez-Miles F (2019) **The first Paratropididae (Araneae, Mygalomorphae) from Colombia: new genus, species and records.** *ZooKeys* 830: 1-32. https://doi.org/10.3897/zookeys.830.31433

New snakes found in South America

Much still remains to be learnt about the snake fauna present in South America. Consisting of as many as 140 species, *Atractus* is the most diverse snake genus in the world, even though its distribution is restricted exclusively to parts of Central and South America. However, this total could ultimately turn out to be higher, given the fact that no less than 33 new members of this group of colubrid ground snakes have been discovered during the past decade.

▲ **Various *Atractus* species were previously known from Ecuador. These two examples - the big ground snake (*A. major*) and the black ground snake (*A. elaps*) reflect the diversity in appearance that is characteristic of this group.** Photos by Dr Morley Read/www.shutterstock.com

Nor is it necessarily a matter of going out into the field to find them. A team of scientists, led by Alejandro Arteaga of Tropical Herping, Ecuador, has shown that the result of a lack of DNA information in the original descriptions of many of these species is the reason for this situation. There have been a lot of specimens sitting in museum collections that remain either misidentified, or anonymous.



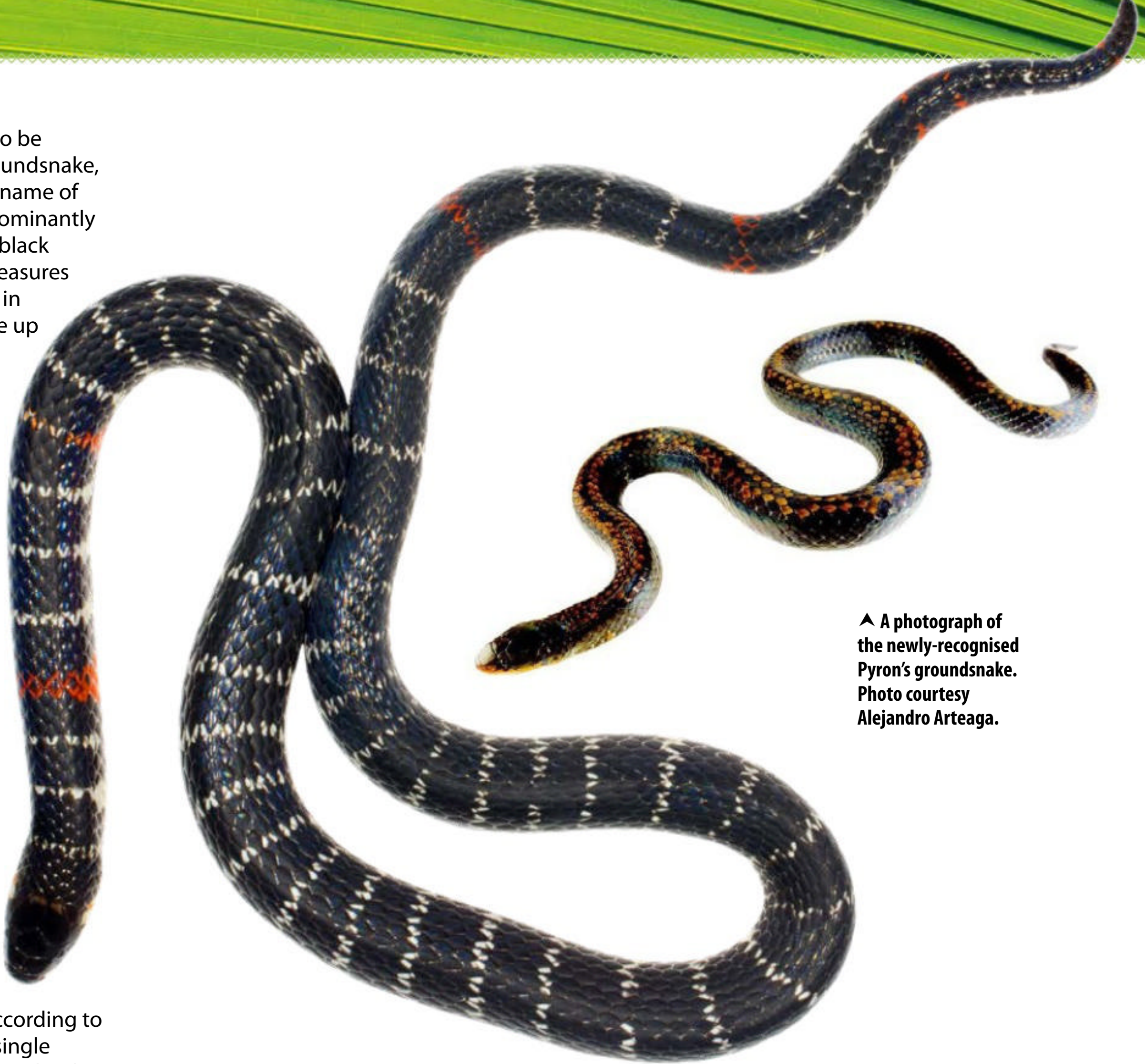
◀ **Named because of where it was discovered, this is the Cerberus ground snake.**
Photo courtesy Alejandro Arteaga.

In order to address the issue around the problematic identification of these snakes and their correct placement in the tree of life, the scientists have studied the hereditary molecular differences in the genus by using both newly-collected specimens, as well as previous publications on the species occurring in the Pacific lowlands and the adjacent Andean slopes.

Their research results has just resulted in the publication of a new paper, describing a total of three new species from Ecuador. In addition, the researchers propose a new species group and a redefinition of a previously established one.

Santa Marta
Barranquilla
Monteria
Bucaramanga
VENEZUELA
PANAMA
Medellin
Bogotá
COLOMBIA
Cali
Neiva
Tumaco
Popayan
Mitú
Putumayo
ECUADOR
Quito
Cuenca
Guayaquil
Machala
Loja
Iquitos
PERU
Moyobamba
Piura
Pucallpa
Ucayali
Tefé
Rio Branco

▲ **Three new species have been identified from Ecuador.** Image courtesy TonelloPhotography/www.shutterstock.com



A photograph of the newly-recognised Pyron's groundsnake. Photo courtesy Alejandro Arteaga.

An unusual name

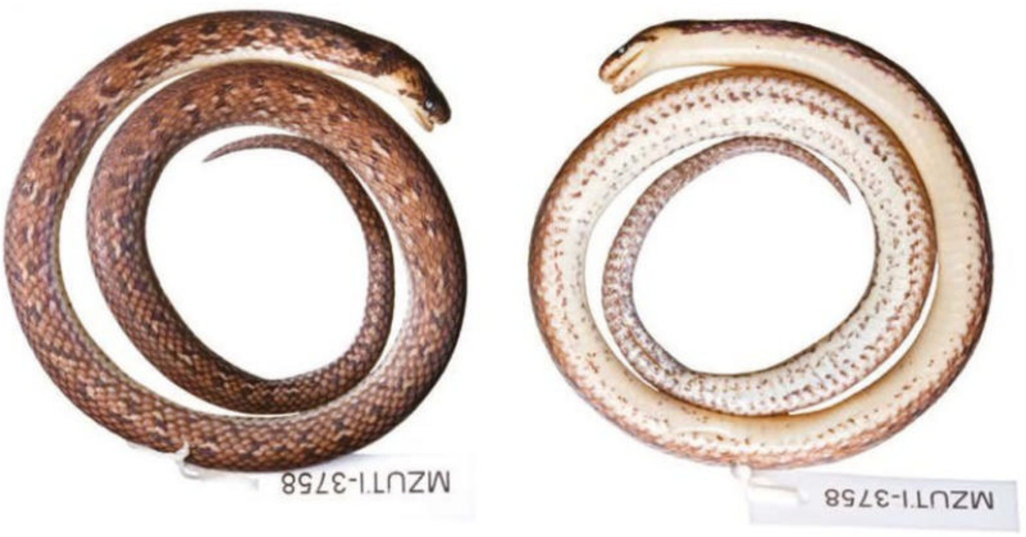
One of the new species is to be referred to as Cerberus groundsnake, known formally under the name of *Atractus cerberus*. It is predominantly brown in colour with faint black longitudinal bands, and measures between 21-31cm (8-12in) in length. The biologists came up with the curious name for this species thanks to the unusual location where they spotted the first known specimen. Encountered at the gates of the new Refinería del Pacífico, a massive industrial oil-processing plant, the snake's presence here brought to mind the multi-headed monstrous dog Cerberus, known to be guarding the gates of the underworld, according to Greek mythology.

Critically endangered already

In terms of their conservation status, the scientists have proposed the Cerberus groundsnake to be listed as critically endangered, according to the IUCN criteria, since its single known habitat is very likely to be the only one, being isolated from any other similar habitats. Moreover, it comprises a relatively small patch of land, which in turn is declining in both size and quality due to deforestation.

According to the IUCN criteria, critically endangered status is given to species whenever the best available evidence indicates that they are facing an extremely high risk of extinction in the wild. The other two new species, the indistinct (*Atractus esepe*) and the Pyron's (*Atractus pyroni*) groundsnakes are to be listed as 'Data Deficient', based on the IUCN's listing criteria as information about them is currently insufficient for their risk of extinction to be assessed.

Having increased the number of *Atractus* species in Ecuador to twenty-seven, the scientists expect that the count will rise even further. "We hope that the new genetic and morphological data which we have collected will encourage other researchers to examine species boundaries in this genus, as clearly, there is much still to be discovered," adds Alejandro Arteaga.

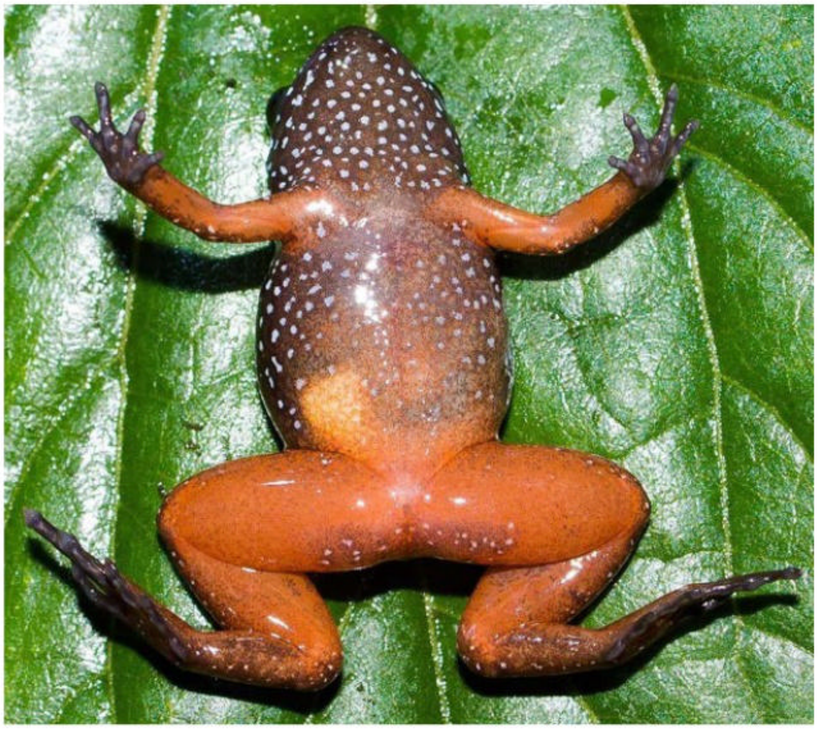


One of the three new additions to the *Atractus* genus. This is the indistinct groundsnake. Photo courtesy Alejandro Arteaga.

Further information

Arteaga A, Mebert K, Valencia JH, Cisneros-Heredia DF, Peñafiel N, Reyes-Puig C, Vieira-Fernandes JL, Guayasamin JM (2017) **Molecular phylogeny of *Atractus* (Serpentes, Dipsadidae), with emphasis on Ecuadorian species and the description of three new taxa.** *ZooKeys* 661: 91-123. https://doi.org/10.3897/zookeys.661.11224

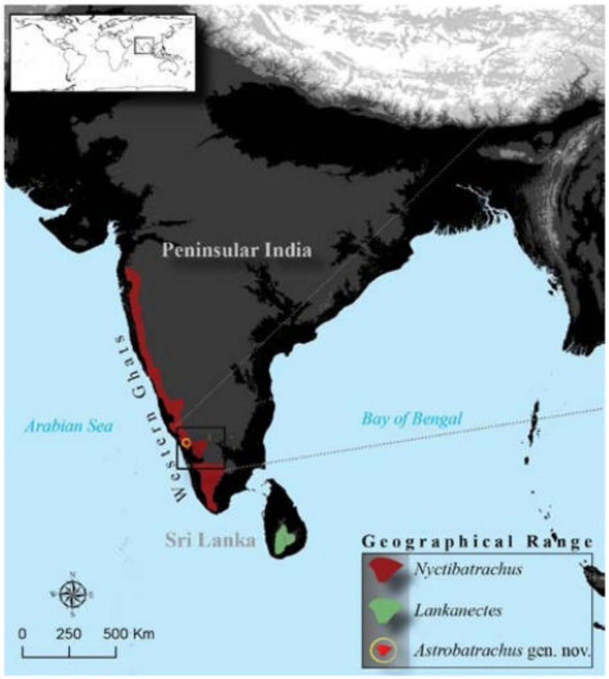
The hidden star



➤ The ventral side of the new frog, revealing its orangish underparts, as well as its pointed toes.
Photo courtesy Seenapuram Palaniswamy Vijayakumar.

The starry dwarf frog is an expert in concealment. Plunging into leaf litter at the slightest disturbance, it has successfully evaded attention for millions of years – until now. This thumbnail-sized species was discovered in India's Western Ghats, one of the world's most significant biodiversity hotspots. Scientists have named this new species as *Astrobatrachus kurichiyana* in recognition of its constellation-like markings and the indigenous people of Kurichiyarmala, who live in the hills where it was found.

But this previously unknown amphibian is not only a new species to science. It's the sole member of an ancient lineage, reflecting a long branch on the frog tree of life that researchers have now classified as a new subfamily, Astrobatrachinae. "This is an oddball frog – it has no close sister species for maybe tens of millions of years," explains David Blackburn, the associate curator of herpetology at the Florida Museum of Natural History. "With frogs, there are still ancient lineages out there awaiting discovery. This gives us one more puzzle piece to think about deep time."



➤ The location of India's Western Ghats, and the new frog, as well as its closest relatives.

A distinctive appearance

Dark brown with a bright orange underbelly and speckled with pale blue dots, the frog blends in exceedingly well with wet leaf litter, and only a few individuals have been found. "The colouration was the first thing that stood out to me, these starry patterns with a blue tinge," says Seenapuram Palaniswamy Vijayakumar, who led the research into the new species, and is now a postdoctoral fellow at George Washington University. "We hadn't seen anything like this before."

The starry dwarf frog is an expert at concealment, and not just because of its appearance, but also thanks to its behaviour. Plunging into leaf litter at the slightest disturbance, it has successfully evaded attention for millions of years – until now. The thumbnail-sized species was discovered in India's Western Ghats, one of the world's most significant biodiversity hotspots. Scientists have named the frog *Astrobatrachus kurichiyana*, reflecting its constellation-like markings and the indigenous people of Kurichiyarmala, the name of the range of hills where it was found.

This frog is not only a new species to science. It's the sole member of an ancient lineage, representing a long branch on the frog tree of life that researchers have classified as a new subfamily, now known as Astrobatrachinae. "This is an oddball frog – it has had no close relatives for maybe tens of millions of years as far as we know," admits David Blackburn, the associate curator of herpetology at the Florida Museum of Natural History. "With frogs, there are still ancient lineages out there awaiting discovery. This gives us one more piece of the puzzle to think about deep time."

Almost overlooked!

The remarkable significance of the starry dwarf frog was not initially appreciated in amongst the number of new species that Vijayakumar and his then-doctoral supervisor Kartik Shanker were finding on a series of expeditions to the Western Ghats, a mountain range extending some 1600km (1000ml) along India's southwestern coast.

Vijayakumar and Shanker, associate professor at the Indian Institute of Science, had designed a meticulous study, covering multiple elevations, habitats and hill ranges to record and map the region's frogs, lizards and snakes.

"When we started sampling, we realised we were digging up a huge treasure," Vijayakumar explains. "This was one among 30 species we captured one night, and while I took photos of it, none of us paid much attention to it."

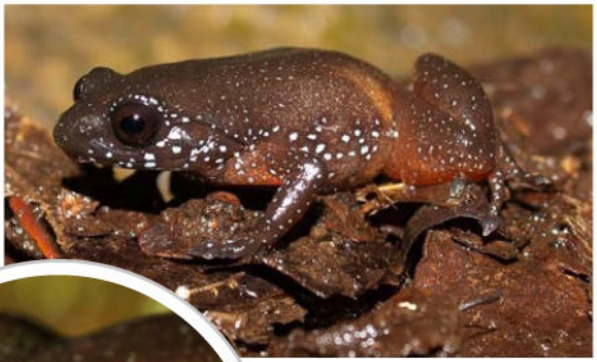
The next morning, on a chilly, wet stroll over the grasslands – watching the ground for leeches – Vijayakumar spotted another of the unusually patterned frogs. "I picked it up and said, 'Hey, this is the same guy I photographed last night,'" he continues. "As a greedy researcher, I kept it, but at that point in time, it wasn't too exciting for me. I didn't realise it would become so interesting."

An international effort

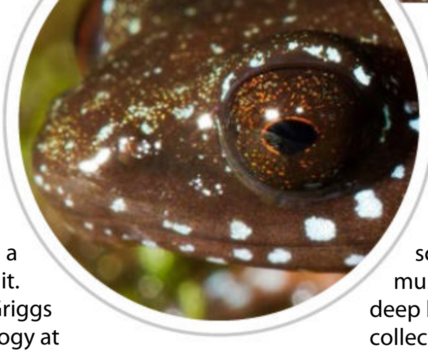
Years passed before Vijayakumar and Shanker could turn their attention to the unknown frog species and assemble a research team to describe it. Alex Pyron, the Robert F. Griggs associate professor of biology at George Washington University and now Vijayakumar's adviser, analysed the frog's genetics, and Florida Museum associate scientist Edward Stanley CT scanned the frog, revealing its skeleton and other internal features.

Thanks to CT technology and the internet, the starry dwarf frog could traverse more than 14,000km (8700ml) from Pune, India, to Blackburn's computer monitor in Gainesville, Florida, almost instantly. "I've never physically seen this species that we've put all this effort into describing," Blackburn explains. "Once specimens are digitised, it really doesn't matter where they are. The strengths that Ed and I could contribute to the team – comparative anatomy – were things we were able to do digitally."

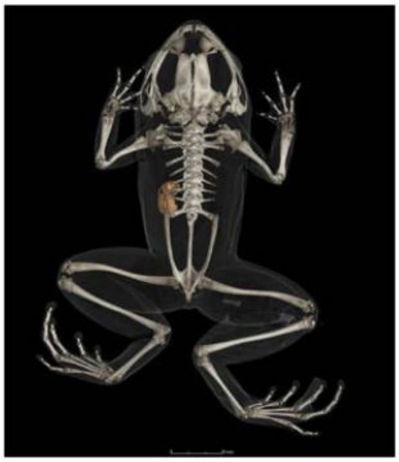
Blackburn and Stanley could instantly compare the starry dwarf frog's bone structure to other frog species from the Western Ghats that have been imaged as part of the openVertebrate project, known as oVert, an initiative to scan 20,000 vertebrates from museum collections. "We have this deep bench of CT data that makes collections amassed over hundreds of years instantaneously available, not just to researchers, but to anyone with a computer," says Stanley.



⮝ **The distinctive appearance of the starry frog, in terms of its colouration and patterning, have helped it to remain hidden amongst the leaf litter where it occurs.** Photo courtesy K. P. Dinesh.



⮝ **When seen in close-up, the star-like speckling of these frogs is unusual, being tinged with blue, which is an uncommon colour in the case of frogs found on the Western Ghats.** Photo courtesy Seenapuram Palaniswamy Vijayakumar.



⮜ **Computerised tomography (CT) scanning allowed researchers to study the internal characteristics of the previously unknown frog, and confirm here that they eat snails.** Photo courtesy Florida Museum: image by Edward Stanley.

An ancient survivor

The team found that the starry frog's closest relatives are found within the family Nyctibatrachidae, a group of nearly 30 species native to India and Sri Lanka. But their last common ancestor could date back tens of millions of years. "This newly-discovered frog is a relic. It's remarkable that they have survived so long. This lineage could have been knocked off at any point in time," Vijayakumar says. "Irrespective of who we are, we should be celebrating the very fact that these things exist."

Scientists have found many ancient lineages of frogs in the Western Ghats, whose biodiversity stems from its history and distinct geography. India, once part of Africa, split from Madagascar about 89 million years ago and drifted northeast, eventually colliding with the Asian mainland and giving rise to the Himalayas. But its long isolation as an island provided a fertile ground for the evolution of new life forms and may have sheltered species that disappeared elsewhere.

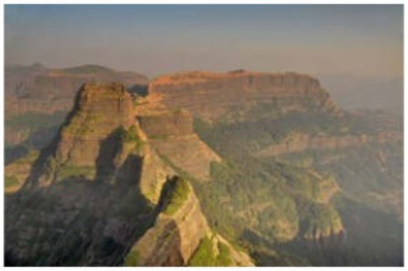
This is especially true of the Western Ghats, which is much like a network of islands, according to Vijayakumar. The elevated region has been cross-sectioned into separate hill ranges by millions of years of erosion and climatic changes. "It's a perfect scenario for the creation of new species," he says.

⮝ **The isolated hill ranges of the Western Ghats act much like islands, preserving lineages of frogs that are found nowhere else.** Photo courtesy of Seenapuram Palaniswamy Vijayakumar.

Mysteries remain…

One particular question which he and Blackburn are interested in exploring further is whether peninsular India's frogs are the descendants of African ancestors, or if they first originated in Asia and then moved south. Finding ancient lineages like Astrobatrachinae can help to fill in in the region's distant biological past, but the starry dwarf frog still retains many mysteries of its own. Researchers still do not know its life cycle, the sound of its call or whether the species is threatened or endangered.

Vijayakumar says that when study co-author K.P. Dinesh of the Zoological Society of India returned to the hill range where the frog was first found, he searched the whole forest floor and hardly saw any individuals. "This frog is so secretive. Just one hop into the litter, and it's gone from sight," he says.



⮝ **The Western Ghats has been likened to a network of islands.** Photo Vihang Ghaisasi/www.shutterstock.com

Further information

Seenapuram Palaniswamy Vijayakumar, Robert Alexander Pyron, K. P. Dinesh, Varun R. Torsekar, Achyuthan N. Srikanthan, Priyanka Swamy, Edward L. Stanley, David C. Blackburn, Kartik Shanker. **A new ancient lineage of frog (Anura: Nyctibatrachidae: Astrobatrachinae subfam. nov.) endemic to the Western Ghats of Peninsular India.** *PeerJ*, 2019; 7: e6457 DOI: 10.7717/peerj.6457

How some sea snakes stay safe

Marine biologists from the School of Biological Sciences, based at the University of Adelaide in Australia, working with colleagues from the University of Western Australia, the University of Bristol in the UK, and the Natural History Museum, London have discovered that the tail skin of some sea snakes contains two interesting genes. One of these contains a light-sensitive protein, and the other is responsible for converting light into information that passes through the nervous system. As a result, olive sea snakes (*Aipysurus laevis*) and other *Aipysurus* species know when to move their paddle-shaped tail away from light. The researchers believe this is an adaptation to keep their vulnerable tail hidden from sharks and other predators.

⮝ An olive sea snake (*Aipysurus laevis*) in its marine habitat, displaying its paddle-like tail. Sea snakes spend their entire lives at sea and must come up to the surface regularly to breath air. Photo courtesy Chris Malam.

A unique feature

Jenna Crowe-Riddell explains that these sea snakes spend their entire lives at sea, swimming with their paddle-shaped tails and resting at times during the day under coral or rocky overhangs

"Because sea snakes have long bodies, the tail-paddle benefits from having a light-sensing ability of its own," she says. "Remarkably, the olive sea snake was the only reptile, out of more than 10,000 reptile species, that was known to respond to light on the skin in this way."

⮟ Researcher Jenna Crowe-Riddell with a baby stokes sea snake (*Hydrophis stokesii*). Photo courtesy Ruchira Somaweera.

The researchers tested for light-sensitive tails in eight species of sea snake but found that only three had developed this light-sensing ability. They concluded that this unique characteristic probably evolved in the original ancestor of just six closely related Australian species. "There are more than 60 species of sea snake so that's less than 10% of all sea snakes that display this trait," explains Jenna Crowe-Riddell. "We don't know why this rare sense has evolved in just a few *Aipysurus* species."

Links to frogs changing colour

The researchers used RNA sequencing to see what genes are active in the skin of sea snakes. They discovered the gene for a light-sensitive protein called melanopsin, and several genes that are involved in converting light into information in the nervous system.

"Melanopsin is used in a range of genetic pathways that are linked to sensing overall light levels around us. It is even used by some animals, including humans, for regulating sleep cycles and in frogs to change their skin colour as a camouflage," she adds.

Lead scientist Dr Kate Sanders says that the team confirmed the ability of olive sea snakes to sense light in their tails and found the same ability in two other species. "We've identified a shortlist of genes that are likely to be involved in detecting light. But further study will be needed to target these genes before we can really understand the genetic pathways involved in this fascinating behaviour," she adds.

⮝ An olive sea snake photographed on Australia's Great Barrier Reef. Their colouration helps them to blend in here, but their distinctive tail can leave them vulnerable. Photo courtesy Richard Ling - Flickr, CC BY-SA 2.0.

Further information

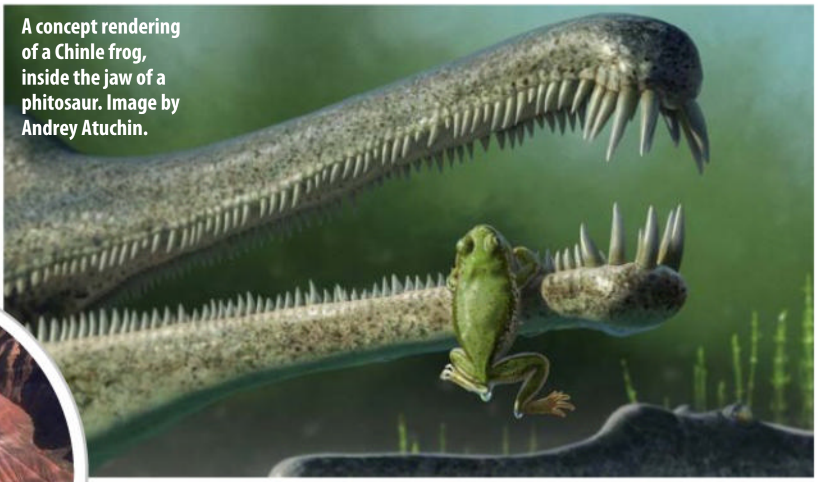
Jenna M. Crowe-Riddell, Bruno F. Simões, Julian C. Partridge, David M. Hunt, Steven Delean, Julian G. Schwerdt, James Breen, Alastair Ludington, David J. Gower, Kate L. Sanders. **Phototactic tails: Evolution and molecular basis of a novel sensory trait in sea snakes.** *Molecular Ecology*, 2019; DOI: 10.1111/mec.15022

Oldest frogs yet known unearthed in the USA

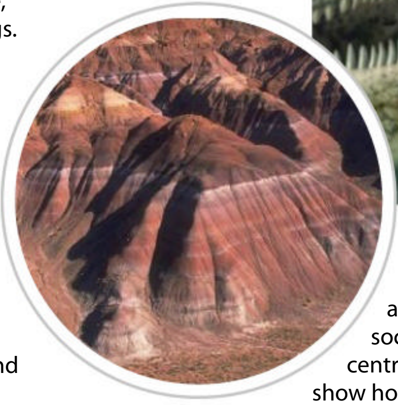
A team of palaeontologists led by Virginia Tech's Michelle Stocker and Sterling Nesbitt of the Department of Geosciences have identified fossil fragments of what are thought to be the oldest known frogs in North America.

The fossils are composed of several small pieces of hip bone, called an ilium, from Chinle frogs. These amphibians represent a distant, long-extinct branch on the family tree of modern frogs, although they are not direct ancestors. The fossil fragments were packed into rock and are smaller than an eyelash.

They represent the first known and earliest equatorial remains of a salientian — the group containing living frogs and their most-closely related fossil relatives — from the Late Triassic, roughly 216 million years ago. The name that has been given to the frog derives from where its remains were found, within the Chinle Formation of Arizona.



A concept rendering of a Chinle frog, inside the jaw of a phitosaur. Image by Andrey Atuchin.



⌃ The Chinie area of Arizona was where the fossilised remains of the new amphibian were discovered.
Photo PD.

Frogs and dinosaurs

"This new find highlights just how much there is still to learn about the Late Triassic ecosystem and how much we find when we just look a little closer," Stocker explains. "We're familiar with the charismatic dinosaurs from the Chinle Formation, but we know that based on other ecosystems, they should make up a small percentage of the animals that lived together. With this new focus, we're able to fill in a lot of those missing smaller components with new discoveries."

⌄ Virginia Tech Assistant Professor Michelle Stocker holds a rock with an embedded Chinle frog hipbone fossil. Look for the small brownish line with a dot at the bottom - the remains are very small and easily missed!

Coming from multiple individuals, the hip bones are are long and hollow, with a hip socket offset rather than centred. The bones of the frogs show how tiny they were: just a bit over 1cm (0.5in) long. "The Chinle frog could fit on the end of your finger," Stocker adds.

Stocker and her team include researchers from Virginia Tech, Arizona's Petrified Forest National Park, and the University of Florida's Museum of Natural History. Even though the fossils are part of the Chinle frog family, the team are not yet naming the specific fossils. "We are refraining from naming this particular frog because we are continuing to process material that will probably yield additional skull and other fossilised skeletal material that has the potential to be even more informative," Stocker adds.

Tracking back

The Chinle frog shares more features with living frogs and Prosalirus, an early Jurassic frog found in sediments from the present-day Navajo Nation, than to Triadobatrachus, an early Triassic frog found in modern day Madagascar in Africa. "These are the oldest frogs from near the equator."

Stocker continues: "The oldest known frogs overall are roughly 250 million years old from Madagascar and Poland, but those specimens are from higher latitudes and not equatorial. During the Triassic, the separate continents we recognise today formed the single landmass named Pangaea. Present-day Arizona was located roughly 10 degrees north of the equator."

⌃ Left to right, Virginia Tech assistant professors Sterling Nesbitt and Michelle Stocker, and PhD student Ben Kligman, all from the Department of Geosciences.

"Now we know that tiny frogs were present approximately 215 million years ago in what has become North America, we may be able to find other members of modern vertebrate communities in the Triassic Period. This discovery also marks the first time that frog fossils have been found directly with phytosaurs and other early dinosaurs," adds her colleague Sterling Nesbitt.

"Our development of methods that recover delicate bones from small-bodied vertebrates enabled this exciting discovery," says fellow researcher Ben Kligman. "Our aim now is to use similar techniques in the Chinle Formation to uncover the early history of other small-bodied animals, including lizards, salamanders, turtles, and mammals."

Further information

Michelle R. Stocker *et al*. **The earliest equatorial record of frogs from the Late Triassic of Arizona.** *Biology Letters* (2019). DOI: 10.1098/rsbl.2018.0922

The death roll increases

The iconic 'death roll' of alligators and crocodiles may be more common among these species than previously believed, according to a new study. Contrary to popular belief, these reptiles are unable to chew, so they use a powerful bite coupled with a full-bodied twisting motion—nicknamed the death roll—to disable, kill, and dismember their prey into smaller pieces. The lethal movement is characteristic of both alligators and crocodiles, and has been featured in numerous movies and nature documentaries.

Until now though, the death roll had only been documented in a few of the 25 living crocodilian species, and notably the bigger, more aggressive ones such as the Nile crocodile *(Crocodylus niloticus)*. But how many act in this way?

"We conducted tests in all 25 species, and 24 of them exhibited this behaviour," confirms Stephanie Drumheller-Horton, a palaeontology professor in the Department of Earth and Planetary Sciences at University of Tennessee, Knoxville. For the research, Drumheller-Horton teamed up with Kent Vliet from the University of Florida and Jim Darlington, curator of reptiles at the St. Augustine Alligator Farm.

Not just about food…

It was previously believed that slender-snouted species, like the gharial *(Gavialis gangeticus)*, didn't roll because their diets consist of small prey like fish which were eaten whole. But it turns out that feeding is not the only time the animals might roll. "Aggression between individual crocodylians can become quite intense, often involving bites and death rolls in establishing dominance or competition for females," Vliet says.

So which was the only species where this behaviour was not observed during this study? It was in the case of Cuvier's dwarf caiman *(Paleosuchus palpebrosus)*, which did not perform a death roll under experimental conditions, although, as Jim Darlington admits, it is equally possible that the individuals involved were just being uncooperative!

And the fossil ancestors of modern crocodiles? If they share a similar body plan and lifestyle with their modern counterparts, it is likely that they displayed death rolling behaviour as well. "Many of the ancestors of today's crocodylians have played the role of semi-aquatic ambush predators since the Age of Dinosaurs, so it's likely they hunted and behaved in a similar way too," says Drumheller-Horton.

▲ **It is now clear that crocodiles do not just engage in a death roll when hunting.** Photo courtesy Sergey Uryadnikov/www.shutterstock.com

◀ **Out of all living species of crocodylian, only Cuvier's dwarf caiman did not display any signs of death-rolling during the course of this study.** Photo courtesy Eric Gevaert/www.shutterstock.com

It used to be thought that slender-snouted crocodylians like the gharial did not engage in death-rolling, but this new study shows that in fact, they do exhibit this behaviour. Photo courtesy Spanker.cz/www.shutterstock.com

Further information

Stephanie K. Drumheller, James Darlington, Kent A. Vliet. **Surveying death roll behavior across Crocodylia.** *Ethology Ecology & Evolution*, 2019; 1 DOI: 10.1080/03949370.2019.1592231

Good news about Pacific turtle populations

Hawksbill turtles have been suffering from hunting pressure and habitat destruction. The survey showed their numbers were not recovering as quickly as green turtle populations.
Photo courtesy Isabelle Kuehn/www.shutterstock.com

Densities of endangered green turtles are increasing around Pacific coral reefs, according to the first comprehensive survey of turtle populations carried out actually in the ocean itself. These sea turtles have long been endangered, largely as the result of human exploitation, with green turtles hunted as a source of food, and hawksbill turtles being sought-after for tortoiseshell.

Global protection efforts, beginning in the 1970s, aimed to reverse this decline. Land-based surveys of breeding and nesting sites have provided important evidence of population sizes, but are limited in scope and have no confirmation from the ocean where the turtles spend the vast majority of their time.

The value of cumulative data

In order to understand the density of the populations of these two turtle species, as well as the environmental and human factors that have affected them, Sarah Becker of the Monterey Bay Aquarium in California and her colleagues combined data from 13 years of in-water visual surveys of turtle abundance near 53 islands, atolls, and reefs throughout the U.S. Pacific. She says: "This study represents one of the largest sea turtle population surveys ever conducted, filling critical gaps on in-water abundance and what impacts on the turtles' population densities."

During a survey of this type, a slow-moving boat tows a pair of divers at about 15m (49ft) below the surface, where they record details of habitat and sea life as it comes into view. In all, the surveys covered more than 7,300km (4536ml) in straight lines, and observed more than 3,400 turtles of the two species. The data showed that American Samoa had the highest density of hawksbills, while the Pacific Remote Islands Area, a mostly uninhabited region about 1600km (1000ml) southwest of Hawaii, had the most green turtles.

Not such good news for hawksbills

Hawksbill numbers were far lower (comprising less than 10% of green turtle counts), indicating that serious conservation threats still exist for this species. Density of green turtles were driven primarily by ocean temperatures and productivity, but historical and present-day human impacts played a role, according to the survey findings.

PACIFIC ISLANDS
Australia

⮝The survey concentrated on the Pacific islands. The highest hawksbill turtle count was in the area of Western Samoa, in the central region of the map.
Photo courtesy Olinchuk/www.shutterstock.com

Over the survey period, green turtle populations were found to be either stable or had increased. The lowest density but the highest annual population growth was found in the Hawaiian Islands, suggesting that protective regulations may be paying off here, allowing green turtle populations to rebound.

⮜The investigation revealed that green turtle numbers were growing at their fastest here in the Hawaiian Islands.
Photo courtesy HurleySB/www.shutterstock.com

Further information

Sarah L. Becker, Russell E. Brainard, Kyle S. Van Houtan. **Densities and drivers of sea turtle populations across Pacific coral reef ecosystems.** *PLOS ONE*, 2019; 14 (4): e0214972 DOI: 10.1371/journal.pone.0214972

Sea turtles in trouble

New research has detailed how environmental stressors, including heavy metals, linked with human activity are harming coastal green sea turtle populations. This investigation was triggered in the aftermath of a catastrophic mass death of green turtles off the Australian coast, and has focused on evaluating turtle health, water quality and other factors.

"We found evidence of heavy metals – particularly cobalt – in sea turtle populations where we also saw signs of illness," says Mark Flint, programme head of Zoo and Wildlife Conservation Medicine and Ecosystem Health in the College of Veterinary Medicine at The Ohio State University.

"Although we can't be sure what caused this, there were cyclones and major flooding in this part of Australia two years prior to the start of our study, and that could have drawn out sediment rich in heavy metals that had been lying in rivers and streams without causing a problem for the past 50 years up until then," he adds.

▲ **It's not only plastic that is a threat to sea turtles today. Other, less evident dangers from human activity pose serious hazards.** Photo courtesy William Bradberry/www.shutterstock.com

Background to the study

Green turtles *(Chelonia mydas)*, are an endangered species, and one of the largest sea turtles in the oceans today, weighing in at as much as 180kg (400lb) once fully grown. These turtles are so-called because of the greenish colour of their body fat however, rather than their shells, and are found mainly in tropical and subtropical water.

▲ **Mark Flint examining a green turtle in the field.** Photo courtesy Mark Flint/Ohio State University.

The World Wide Fund for Nature-Australia (WWF) provided funding for this research, and led the Rivers to Reef to Turtles project under which it was conducted. Large populations of green turtles live, feed and nest on Australia's Great Barrier Reef, along the east coast, favouring the bays and protected shores here and around the offshore islands. The scientists hope that this new research will now inform conservation efforts going forward.

The Rivers to Reef to Turtles project examined green turtles at two northern Queensland bays – Cleveland and Upstart – known to be impacted by urban and agricultural human activities and at a third far more remote and pristine area, in the Howick group of islands, which form part of the Great Barrier Reef Marine Park.

The significance of barnacles

Following up on a high number of turtle deaths that conservationists were attributing to a wide range of causes, including run-off from agriculture, industrial toxins and climate change, the team conducted physical examinations and tested the turtles' blood over time, looking for signs of contaminants and illness.

They also counted the number of barnacles on the turtles. Flint's previous work has shown that high barnacle counts on turtles' undersides correspond to poor health. The theory behind that? When healthy and feeding normally, a turtle's trips to the sea floor to eat sea grass effectively scrape away any build-up of barnacles. If green turtles are not eating well, however, this enables the barnacles to accumulate on the shell.

"An unhealthy turtle often has trapped air in its shell and is buoyant,

Cleveland Bay is an area that has become increasingly urbanised over recent years, right down to the waterfront as seen here. Photo courtesy Michelle Bain/www.shutterstock.com

Green turtles are important in maintaining the overall health of seagrass beds.
Photo courtesy Rich Carey/www.shutterstock.com

meaning it can't dive down for food. It's almost like a balloon," Flint explains. "Also, a turtle that can't dive spends more time on the surface of the water where algae and barnacles can grow better."

In cases where the researchers found dead turtles, they conducted in-depth autopsies.

The research team found elevated levels of an enzyme called creatinine kinase in turtles at Cleveland Bay. This particular enzyme typically increases after muscle injury or illness. And they discovered elevated white cell counts in turtles at Upstart Bay. White blood cells proliferate when an animal is fighting infection.

One in five of the juveniles examined at Cleveland Bay had high barnacle levels (with 16 or more being present) and one in 10 of the young turtles at Upstart Bay had excessive barnacle growth. This level of barnacle growth was not seen in any of the turtles at the "pristine" control site.

▲ A high incidence of barnacles, especially on the underside of the shell, can indicate health issues in sea turtles.
Photo courtesy Leo Lamas/www.shutterstock.com

▼ Changing weather patterns may explain the build-up of heavy metals in the turtle population, being a reflection of past rather than recent pollution. Photo courtesy Somporn Suebhait/www.shutterstock.com

By the end of the study, the researchers saw some evidence that the population in Cleveland Bay was returning to normal, but the problem still remains for turtles in Upstart Bay.

A range of hazards

This multidisciplinary approach is the first attempt to look in detail at this population of turtles and the potential links between environmental toxins and the turtles' well-being. The researchers suspect that the unhealthy signs seen in the turtles that live in the areas affected by urbanisation, farming and industry are connected to contaminants in their ecosystem. In particular, the study team found evidence of heavy metals, primarily cobalt, in the turtles' blood.

Green turtles migrate long distances between feeding grounds and from the beaches on which they hatched. The reptiles are threatened by over-harvesting of their eggs, hunting of adults, being caught in fishing gear and loss of nesting beach sites, according to the WWF. The green turtle is the only "vegetarian" sea turtle, eating mostly seagrass and algae, which relates to its ecological importance.

Impacts in the ecosystem

When green turtles graze on seagrass beds, that vegetation remains productive – something the WWF compares to mowing the lawn. The turtles also recycle nutrients they digest, making them available to other animals and plants, which ultimately is important for the survival of invertebrates and fish, some of which people eat.

According to Mark Flint, the monitoring of sea turtle health is important because with their long lifespans and tendency to stay in one place, they can potentially be symptomatic of the state of the broader environment. The problem is that their physical responses to environmental assaults and disease are slow-moving, complicating conservationists' ability to draw connections between the environment and sickness and death of turtles.

This new research now gives conservationists and marine biologists a baseline understanding of sea turtle health and response to environmental stressors, which will better enable them to assess the health of a turtle population after an issue arises and assess this over time. It will also provide tools to help decision-makers develop environmental mitigation strategies when problems do arise.

Further information

Mark Flint, Anne-Fleur Brand, Ian P. Bell, Christine A. Madden Hof. **Monitoring the health of green turtles in northern Queensland post catastrophic events.** *Science of The Total Environment*, 2019; 660: 586 DOI: 10.1016/j.scitotenv.2019.01.065

Tortoises on the move

Galápagos giant tortoises, sometimes referred to as the 'Gardeners of the Galápagos', are creatures of habit. During the cool dry season, the highlands of the volcano slopes are engulfed in cloud which allows the vegetation to grow, despite the lack of rain. On the lower slopes, however, there is no thick fog layer, and vegetation is not available year round. Adult tortoises thus spend the dry season in the higher regions, and trek back to the lower, relatively warmer zones where there is then abundant, nutritious vegetation once the rainy season begins.

Pursuing the same path

The tortoises often follow tradition migration routes over the course of many years in order to find food of optimal quality, and maintain their body temperature. The timing of this migration is essential for keeping their energy levels high, and climate change could disrupt a tortoise's ability to migrate at the right time. Researchers have now used GPS to track the timing and patterns of tortoise migration over multiple years for the first time.

"We had three main goals in the study," explains Guillaume Bastille-Rousseau. "One was determining if tortoises adjust their timing of migration to the current environmental conditions. Secondly, if so, what clues do they use to adjust the timing, and finally, what are the energetic consequences of migration mis-timing for tortoises?"

The scientists expected the migrations to be timed with current food and temperature conditions

⮝ The movements of Galápagos giant tortoises are now being tracked by means of GPS, giving accurate insights into how they travel.
Photo courtesy FOTOGRIN/ www.shutterstock.com

▲ **Galápagos giant tortoises migrate from arid lowlands to foggy, cooler uplands during the dry season to find more consistent, if not as nutritious, vegetation.** Photo courtesy Guillame Bastille-Rousseau.

▲ **Feeding in forested areas means that Galápagos giant tortoise are important in helping to distribute seeds around the islands where they occur.** Photo courtesy Use Bergwitz/www.shutterstock.com

▼ **Some forms of Galápagos giant tortoises are particularly well-equipped to browse on shrubs and low-growing trees, thanks to their raised shell shape, combined with their long necks.** Photo courtesy marktucan/www.shutterstock.com

because many other migratory species operate that way. Bastille-Rousseau says: "Many animals, such as ungulates, can track current environmental conditions and migrate accordingly – this is what researchers sometime refer to as 'surfing the green wave'."

Unexpected findings

Contrary to what the researchers had anticipated, however, migration in the case of Galápagos giant tortoises is weakly associated with current conditions such as fog, rain, and temperature. For instance, if it is unseasonably arid, it appears the tortoises do not take that variation into account when deciding it is time to migrate. It is unclear at this point whether they are basing their migration decisions on memories of past conditions or if they are simply incorrectly assessing current local conditions.

Bastille-Rousseau says the team is surprised by the mismatch, stating "tortoise timing of migration fluctuated markedly over the years, often by more than two months. This indicates that migration for tortoises may not just be about foraging opportunities. For example, female tortoises have to make decisions related to nesting, and we definitely still have a lot to learn about migration in giant tortoises."

Fortunately, this sub-optimal timing may not yet have critical impact on tortoise health. Potentially due to their long lives of up to 100 years or more and large body size, bad timing of migration has less significant consequences for giant tortoises compared with small, short-lived animals. Giant tortoises can go up to a year without eating and survive, while other migrating species must eat more regularly to sustain their energy levels.

Effects on the environment

Giant tortoises are important ecosystem engineers in the Galápagos, responsible for long-distance seed dispersal through their droppings, and their migration is key for the survival of many tree and plant species. How the tortoises' variations in migration timing will affect the rest of the ecosystem is still unclear. Since these reptiles do not seem to be tracking annual variation in environmental conditions, it is quite possible that the mistiming of migration will keep increasing in the future.

"One concern is that at some point in the future," Bastille-Rousseau adds, "migration may not be an optimal strategy for tortoises. There may be a reduction in the number of individuals undertaking these long-distance movements. This would likely have cascading detrimental consequences for the whole ecosystem."

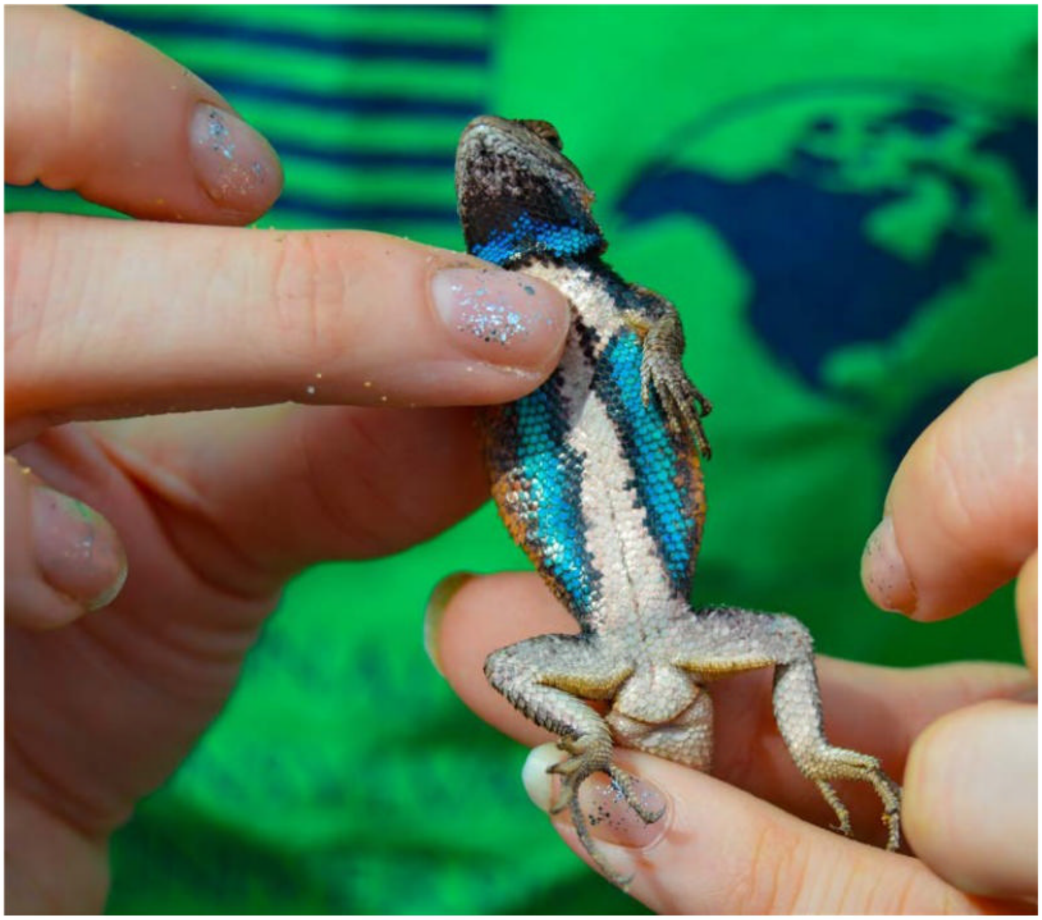
Further information

Guillaume Bastille-Rousseau, Charles B. Yackulic, James P. Gibbs, Jacqueline L. Frair, Freddy Cabrera, Stephen Blake. **Migration triggers in a large herbivore: Galápagos giant tortoises navigating resource gradients on volcanoes.** *Ecology*, 2019; e02658 DOI: 10.1002/ecy.2658

Defining characteristics of male lizards are resilient to stress

Physical traits and behaviours that make a lizard attractive to potential mates and deter predators may be of such significant that they do not change in the face of stress. This has been confirmed in a new study by researchers at Penn State University. Their results reveal that the blue and black badges on the throats and abdomens of male fence lizards – and signalling behaviours associated with them – are not affected by low levels of stress-associated hormones, unlike many other traits.

"Animals in the wild experience stress every day, when they flee from predators, fight with others over food, or face extreme weather," explains Kirsty MacLeod who led the research. "But they are facing increasing amounts of stress due to increasing interactions with people, a changing climate, and other lifestyle impacts linked to human activity. It is therefore rapidly becoming more important to understand the myriad effects of stress on the population health of species as a result."



The blue and black areas on a male eastern fence lizard's chin and abdomen serve to attract potential mates and fend off competitors. Photo courtesy Hunter Kauffman/www.shutterstock.com

Sexing fence lizards is straightforward as females are much duller in colouration than males, lacking the blue and black areas on the underparts of their bodies.
Photo courtesy Sari ONeal/
www.shutterstock.com

Stress and reproduction

The researchers studied the effects of stress on secondary sexual traits, which, like a deer's antlers or a bird's brilliant colours, are important in attracting mates or warding off potential rivals, and ultimately contribute to an animal's ability to reproduce. Specifically, they studied the blue and black areas that appear on the throats and abdomens of male eastern fence lizards.

"Secondary sexual traits are the billboard ads that animals use to advertise their condition," says MacLeod. "Being more colourful or having bigger ornaments – like antlers – than your neighbour, could mean the difference between mating and passing on your genes, or not mating at all. They can also help in maintaining a bigger territory that can provide resources for your offspring and preventing constant attack by rival males.

"If stress impacts on these secondary sexual traits, it could affect which individuals are successful in mating or holding territories, which could in turn impact directly on the evolution and persistence of these populations, even though these traits are often not thought of as being central to population health."

Colour and behavioural displays

The research team found that the colour of a male lizard's blue and black markings is not related to the normal circulating levels of the stress hormone corticosterone in their blood. Additionally, artificially elevating levels of corticosterone,

▲ The use of signalling is potentially more important than the colouration itself, by ensuring the distinctive coloured areas can be seen. You need to look closely at this male to spot his distinctive blue and black patterning. Photo courtesy Isabel Eve/www.shutterstock.com

▲ The location of the brightly-coloured areas on the body of a male fence lizards means that females can recognise potential mates easily, but the predominantly brown colouration over the back still helps to conceal the lizard's presence from predators in the open, as shown here by this male. Photo courtesy Isabel Eve/www.shutterstock.com

replicating the elevation that occurs when a lizard encounters a stressor like a predator, over the course of a few weeks on a repeated basis did not affect badge colour either.

As well as investigating the physical trait of badge colour, the research team also looked at how the trait is displayed through behaviours. Much like a male peacock might raise its colourful tail, so male fence lizards perform push-ups and bob their heads to show off their badges, whether warding off other males or to attract potential mates.

"If stress did not affect colour but did affect the behaviour, such as if the lizards stopped doing push-ups, then it wouldn't matter if their colour was the same because it wouldn't be seen," notes Kirsty MacLeod. "It would be like having a big flashy billboard lying on the ground out of sight."

Stress has no impact

The team found that elevating stress hormones did not affect signalling behaviours, including the number of push-ups or head bobs that the lizards performed. "We know that elevating stress hormones can have significant impacts in this lizard species, including effects on immune function and behaviours that allow them to deal with predators, so these results are particularly interesting," says Tracy Langkilde, professor and head of biology at Penn State.

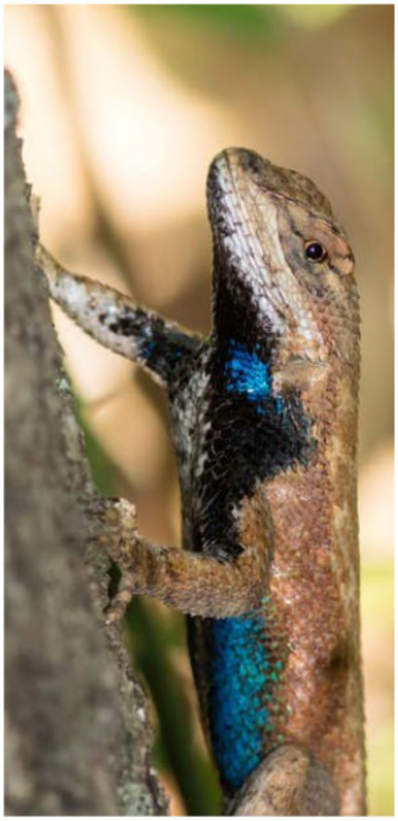
"It may be that low-level stress is not enough to impact these traits. Or that sexual signalling—to find better mates and maintain better territories—is so important that, when lizards experience stress, more resources are allocated to maintain them," she adds.

Follow-up and reflection

Next, the researchers plan to investigate whether maintaining these signalling traits under stress has an increased physiological cost on other aspects of lizard health and survival. The researchers also emphasise that sharing negative results like these, which show that a factor of interest does not have an effect, is valuable, as they provide meaningful information and can challenge existing beliefs.

"It's always cool to show something you expected to have an impact on animals, like stress, does so, but it's equally important to show where there is no impact," explains MacLeod. "If we only reported results that indicate stress having an effect, we might over-estimate the significance of stress. Our results suggest that animals are resilient to stress where it matters: in the context of sexual signalling, which is likely to be critical in determining their ability to reproduce successfully."

▼ A male eastern fence lizard doing push-ups, which feature as part of the display of this species. Photo courtesy Robert Mutch/www.shutterstock.com

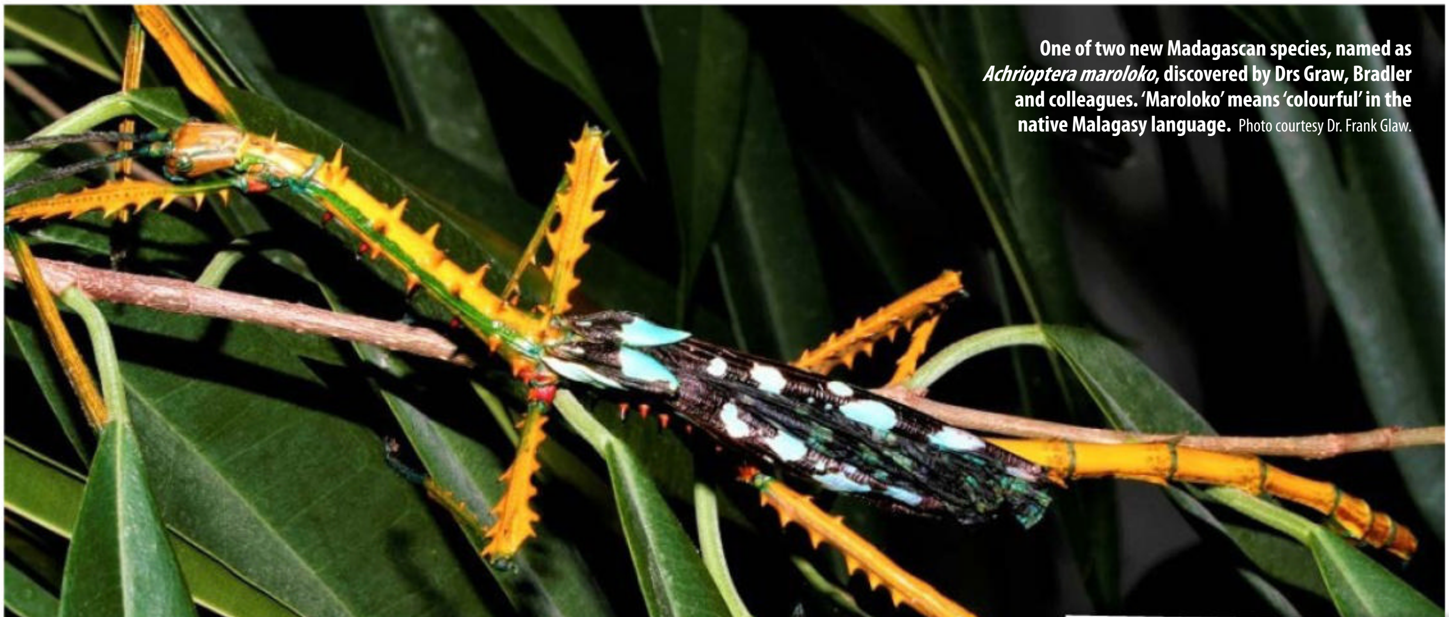


▲ An adult male fence lizard—according to this research, these particular reptiles are not significantly affected by stress when seeking to attract mates. Photo courtesy Frode Jacobsen/www.shutterstock.com

Further information

K. J. MacLeod, G. L. McCormick, T. Langkilde. **Glucocorticoids do not influence a secondary sexual trait or its behavioral expression in eastern fence lizards.** *Scientific Reports,* 2019; 9 (1) DOI: 10.1038/s41598-019-41596-1

Stunning new stick insects discovered



One of two new Madagascan species, named as *Achrioptera maroloko*, discovered by Drs Graw, Bradler and colleagues. 'Maroloko' means 'colourful' in the native Malagasy language. Photo courtesy Dr. Frank Glaw.

Madagascar, lying off the southeast coast of Africa is one of the world's largest islands, and home to some of its biggest insects alive today anywhere on the planet. German scientists have recently discovered two new species of giant stick insect here in this biodiversity hotspot, where they appear to be confined only to the dry forests of the island's northernmost tip.

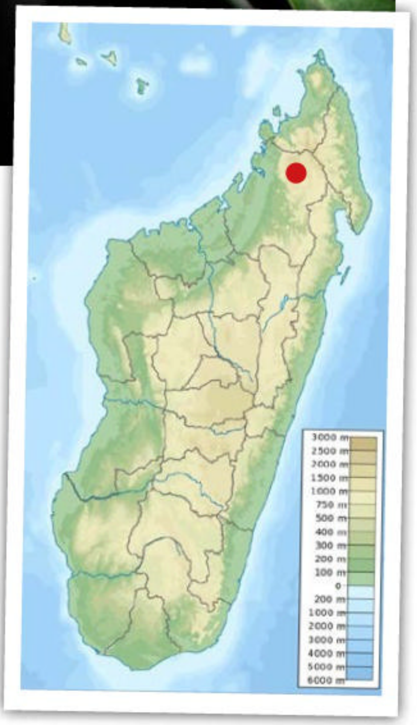
The giant females can measure up to a massive 24cm (9.5in) in terms of their overall length – but it is the smaller males that are most striking in terms of colouration. Remarkably, when they attain sexual maturity, these stick insects abandon their typical twig-like camouflage for a dazzling blue or a multi-coloured shining body covering.

Colour changes

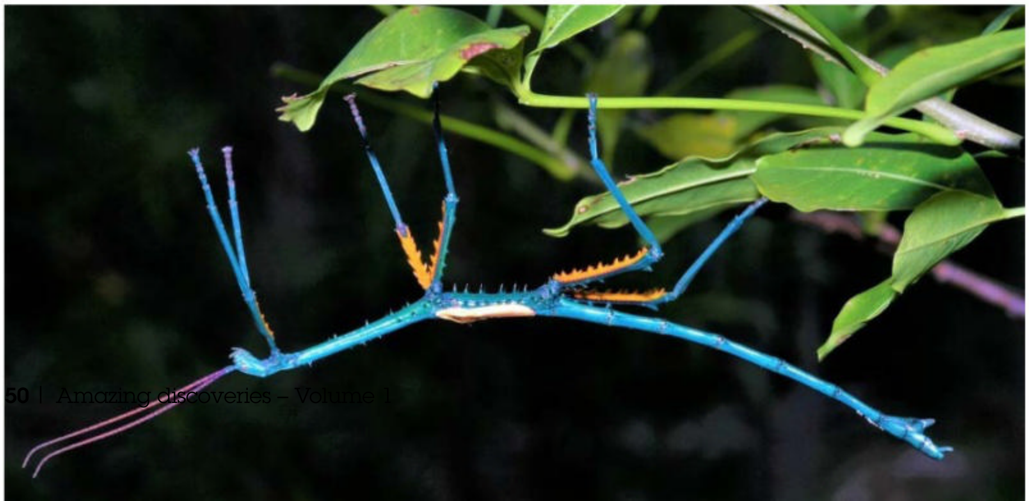
"Nearly all of the 3000+ known species of stick insects try to be inconspicuous and just look like twigs," says Dr. Sven Bradler of the University of Göttingen, Germany. "There are a very few, very large exceptions – and we have just discovered a couple more of them." In two new species of rare giant stick insects, males turn a vivid blue or multicoloured at sexual maturity — but why?

The authors re-examined specimens which they had previously identified as odd-looking examples of two existing giant stick insect species, whose adult males are remarkably bright blue or multi-coloured. "These were similar in size – 15-24cm (6-9.5in) – but generally less spiny and coloured a bit differently to typical examples of their kind," explains Bradler. "Now genetic tests confirm that the quirky individuals are in fact two new species, distinct from the original two but part of the same group. We started off with two, and now have four!"

Bradler's reclassification places members of this group of species as close evolutionary relatives of other Madagascan stick insects, rather than cousins from overseas as previously thought. This is a potentially major finding, as it challenges the prevailing



➤ **The area of Madagascar, in the Montagne des Français Reserve, where the new species were discovered.** Map Urutseg/PD.



➤ **Another of the new phasmid species from Madagascar, discovered by the team. It is now known to science as *Achrioptera manga*, with 'manga' meaning 'blue' in Malagasy.** Photo courtesy Dr. Frank Glaw.

view that sticks insects colonised Madagascar multiple times.

Further insights from captive-breeding

The discovery also prompted the researchers to wonder as to what reproductive advantage or advantages these males might gain from their bright colours that makes it worth exposing themselves in such a way to predators?

Dr. Frank Glaw of the Bavarian State Collection of Zoology in Munich and colleagues have bred the new giant stick insect species in captivity to observe their behaviour. "Males of one species started mating attempts only when they achieved their bright blue colour," he says. This might suggest that the males use their bright colouring to attract a mate. However, it is hard to believe the males could find a mate before being eaten – unless their bright colouring acts as a deterrent to predators.

"Males searching for a mate have to move about more, so pretending to be a stick becomes tricky. Better perhaps to plump for the opposite: a brightly coloured warning," Dr Glaw suggests.

Bright colours – suggestive of toxicity – keep members of other brightly coloured, small species, such as many mantella frogs occurring on Madagascar, safe from predation, acting as a warning sign of toxicity.

⮝ The golden mantella is another seemingly defenceless species whose bright colouration warns would-be predators of danger.

Photo courtesy Vladimir Wrangel/www.shutterstock.com

More to discover

"In support of this idea, all stick insects have neck glands that produce repellant substances, and these are typically well-developed in brightly coloured species. Alternatively, like the Madagascan frogs, some giant stick insects may have developed the ability to accumulate toxins from their food, making them a potentially deadly meal for a predator," adds Dr. Glaw. On the other hand, as he admits, testing these particular hypotheses to obtain meaningful answers will not be straightforward.

Bradler also notes: "In addition of course, more than one factor may have played a role in the evolution of this remarkably conspicuous colouration. So even with more data on mate selection, habits, predators, natural food plants, toxins produced by defence glands and possible accumulation of toxins among giant stick insects, finding evidence for these ideas may still prove difficult."

A future icon?

Whatever its function, the splendid colouring of the male giant stick insects could make them a strong flagship species to promote the unique biodiversity of Madagascar, and the need for its protection, not just of the megafauna found there like the lemurs, but the entire ecosystem, including invertebrates.

"Already the once-uncertain future of these two new species seems secured, with their forest habitat in northern Madagascar now being a hotspot for conservation priorities," says Glaw. "It is vital to maintain awareness and motivation to keep logging at bay. This precious area also harbours the highest density of critically endangered reptiles in Madagascar and is home of one of the most threatened primate species in the world, in the guise of the northern sportive lemur *(Lepilemur septentrionalis)*."

Further information

Frank Glaw, Oliver Hawlitschek, Andreas Dunz, Julia Goldberg, Sven Bradler. **When Giant Stick Insects Play With Colors: Molecular Phylogeny of the Achriopterini and Description of Two New Splendid Species (Phasmatodea: Achrioptera) From Madagascar.** *Frontiers in Ecology and Evolution,* 2019; 7 DOI: 10.3389/fevo.2019.00105

Divided up

Known to science since 1857, what was believed to be a common species of 'true' frog (meaning a member of the family Ranidae), has now been revealed as a group of similar species, rather than an individual one. This is according to British and Costa Rican herpetologists, who recently used DNA barcoding to study the species in question.

Recognised previously as Warszewitsch's frog, whose range was thought to extend from north-eastern Honduras through Nicaragua and Costa Rica southwards to central Panama, it is now thought to represent a group of "cryptic species", according to new research conducted in the Área de Conservación Guanacaste (ACG), Costa Rica, by James Cryer, Dr Robert Puschendorf, Dr Felicity Wynne from the University of Plymouth, and Dr Stephen Price, from University College, London. This phenomenon is now well-documented in the case of tropical amphibians, where high levels of genetic variation within populations of what appears to be a single species surpass levels of diversity found between different, classified species.

Hunting cystic species

By utilising a technique known as DNA barcoding, which compares short snippets of DNA sequences between individuals sampled, the scientists analysed specimens from three different geographic areas within Costa Rica and Panama. In this case, the researchers used sequences derived from mitochondria, the energy-producing "power houses" found in animal cells. Their results indicated there was enough genetic variation to suggest cryptic species are indeed present.

The team chose this particular frog to investigate because cryptic species were previously identified at two Panamanian sites. Now, the samples from Costa Rica broaden the study area, suggesting that there could be multiple species going by the name of Warszewitsch's frog, occurring across its known distribution.

Further investigations

Conservation biologist James Cryer says: "The next step will be to gather more samples throughout the full range of the species. Additionally, if we are to fully discern one species variant from another, further studies that compare the physical, behavioural and ecological characteristics of the frogs, alongside more genetic testing, are needed."

Findings like these are important to help improve our understanding of amphibian biodiversity and assist conservation. "If indeed there are multiple species, it may be that they have different ecological requirements, and therefore different approaches to their conservation are needed," Cryer adds. "This study further reinforces the power of DNA barcoding for rapid, preliminary species identification. It is especially useful in the tropics, where habitat loss, climate change and infectious disease continually threaten many undescribed amphibian species."

Further information

James Cryer, Felicity Wynne, Stephen J. Price, Robert Puschendorf. **Cryptic diversity in *Lithobates warszewitschii* (Amphibia, Anura, Ranidae).** *ZooKeys,* 2019; 838: 49 DOI: 10.3897/zookeys.838.29635

New mini frogs found on Madagascar

Madagascar, in spite of being an island a little larger than mainland France, is known to be home to more than 350 species of frog. The number of recognised species there continues to rise, with many of the newly discovered species being very small.

Mark D. Scherz, from LMU Munich, and Dr. Frank Glaw, Head of the Herpetology Section at the Bavarian State Collection of Zoology in Munich, together with colleagues at the Technical University of Braunschweig and the University of Antananarivo have now named another five new species of tiny frogs recently discovered across the island. These amphibians belong to a group commonly referred to as 'narrow-mouthed' frogs, and represent a highly diverse family found on every continent except Antarctica and Europe.

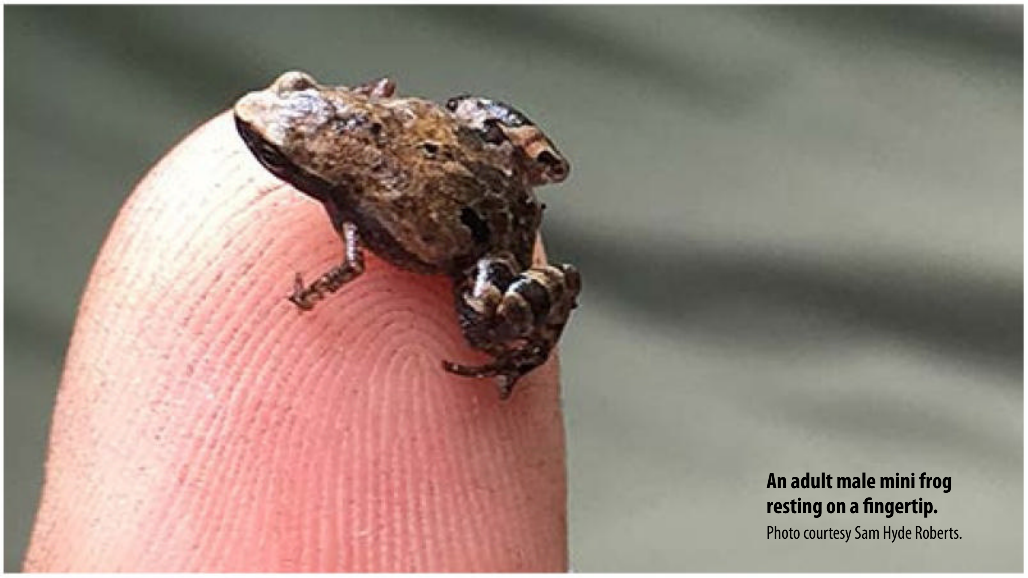
Although most narrow-mouthed frogs are small to moderately large in size, many are tiny. In fact, the group includes the smallest frog in the world – *Paedophryne amauensis* – from Papua New Guinea. Mature specimens in this case reach a length of only 7.7mm (0.3in). What is particularly remarkable is that, in the smallest frogs, miniaturisation has evolved independently – often several times within a single region, as highlighted in this new study.

Hard to distinguish and easily overlooked!

Three of the new species belong to a group that is wholly new to science, which the authors have now formally dubbed mini frogs. The other two new species, *Rhombophryne proportionalis* and *Anodonthyla eximia*, are also just 11-12mm (0.43-0.47in) long, and are much smaller than their closest relatives.

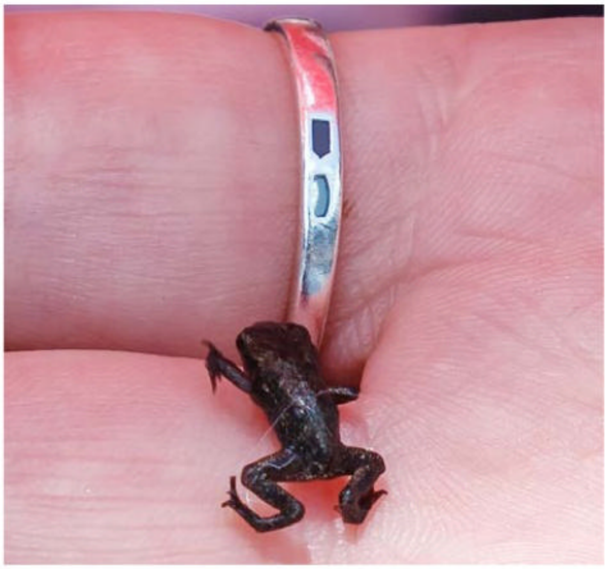
"When frogs evolve small body size, they start to look remarkably similar, so it is easy to underestimate how diverse they really are," explains Mark D. Scherz. "Our new genus name, mini, says it all. Adults of the two smallest species, called mini mum and mini scule, are 8-11mm (0.31-0.43in) long, and even the largest member of the genus, called miniature, at 15mm (0.6in), could sit on your thumbnail with room to spare!"

Finding tiny frogs in leaf litter is hard work. "Calling males often sit at a level of 1-2 leaves deep and stop calling at the slightest disturbance," says Frank Glaw. "It can take a lot of patience to find the frog you are looking for, even though you may initially hear it!"


An adult male mini frog resting on a fingertip.
Photo courtesy Sam Hyde Roberts.

The colouration of many frogs, like these these new discoveries, is predominantly brownish, and makes them hard to spot on the forest floor where they can conceal themselves very effectively. This example is a larger species which is found on Madagascar, known as the Madagascan wood frog *(Aglyptodactylus madagascariensis).*
Photo courtesy David Havel/www.shutterstock.com

⮟ This is the smallest known frog in the world - the newly-discovered species from Madagascar are barely a few millimetres bigger.
Photo courtesy alex_gor/www.shutterstock.com



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Sunbathing slows development

Anoles living on islands tend to be more conspicuous, because they face fewer predators in these surroundings. Photo courtesy ulrich missbach/ www.shutterstock.com

If you've ever spent some time in the Caribbean, you might have noticed that humans are not the only ones keen to soak up the sun's warm rays. Anoles – a group of small tree lizards – spend much of their day moving in and out of shade. But, according to a new study led by assistant professor Martha Muñoz from Virginia Tech and Jhan Salazar from Universidad Icesi, this behavioural "thermoregulation" isn't just affecting their body temperature. Surprisingly, it's also slowing their evolution.

The idea that evolution can be slow on islands is actually somewhat strange. Ever since Darwin's journey to the Galápagos archipelago, islands have become accepted as hotspots of rapid evolution, resulting in many ecologically diverse species that do not occur anywhere else on earth.

Freed from predation

The reason why evolution often goes into overdrive on islands has to do with the ecological opportunity presented by simplified environments. When organisms wash up on remote islands, they find themselves freed of their usual competitors and predators, which allows them to diversify rapidly to fill new niches. This phenomenon of faster evolution is often referred to as the "island effect."

Yet the researchers discovered that physiological evolution in *Anolis* lizards is actually much slower on islands than on the mainland. What is causing their evolution to stall? The same ecological opportunity that frees island organisms from predators also facilitates behavioural thermoregulation.

"Whereas mainland lizards spend most of their time hiding from predators, island lizards move around more, and are able to spend much of their day shuttling precisely between sun and shade in order to meet their needs," says Muñoz, assistant professor in the Department of Biological Sciences in the College of Science.

▲ **An anole *(Anolis chloris)* displaying while benefiting from the sun at the same time.**
Photo courtesy J. Salazar, Virginia Tech.

▼ **Jhan Salazar holds an anole from Colombia. There are important behavioural differences between mainland and island species.**
Photo courtesy J. Salazar, Virginia Tech.

If it gets too hot, island lizards simply go and find a shady spot. When they get cold, they can dash onto a sunny perch to warm up again. By thermoregulating, island lizards are not just buffering themselves from thermal variation. They are effectively shielding themselves from natural selection. If lizards aren't exposed to extreme temperatures, then selection on the basis of their physiology is weakened. The result? Slower rates of physiological evolution. Effectively, island lizards use behavioural thermoregulation like a sunblock against natural selection!

An evolutionary myth

Jhan Salazar says: "Our results show that faster evolution on islands is not a general rule. This slower physiological (body functioning) that is associated with island species stands in stark contrast to changes in their actual morphology (appearance), which has been shown to evolve faster in island anoles.

"When it comes to morphology and physiology on islands, it seems we are looking at different sides of the same coin," he adds. "The same ecological release from predators and competition that allowed for the truly impressive amount of morphological diversification which has appeared quickly among island anoles seems additionally to allow for more behavioural thermoregulation which in turn slows physiological evolution.

"We are discovering that organisms are the architects of their own selective environments," concludes Muñoz, "This in turn means that behaviour and evolution are locked together in a delicate dance. This *pas de deux* tells us something really important about how diversity arises in nature, which has tended to be overlooked in the past."

▲ **A Haitian white-lipped anole *(Anolis coelestinus)*. This is a species found only on the Haitian part of the Caribbean island of Hispaniola.**
Photo courtesy reptiles4all/www.shutterstock.com

Further information

Jhan C. Salazar, María del Rosario Castañeda, Gustavo A. Londoño, Brooke L. Bodensteiner, Martha M. Muñoz. **Physiological evolution during adaptive radiation: A test of the island effect in *Anolis* lizards.** *Evolution*, 2019; DOI: 10.1111/evo.13741

An American symbol on the retreat

It now appears that the American bumblebee is under serious threat of extinction in Canada. Photo courtesy RachelKolokoffHopper/www.shutterstock.com

The American bumblebee – a species once more commonly seen buzzing around Southern Ontario – is now critically endangered, according to a new study led by York University scientists from Toronto, Canada. It found the native North American species, known scientifically as *Bombus pensylvanicus*, is facing imminent extinction in Canada. Many bumblebee species are rapidly declining across North America, and yet are important pollinators needed to fertilise the flowers of many of Canada's crops including apples, blueberries and legumes, as well as countless types of trees, shrubs, and wildflowers.

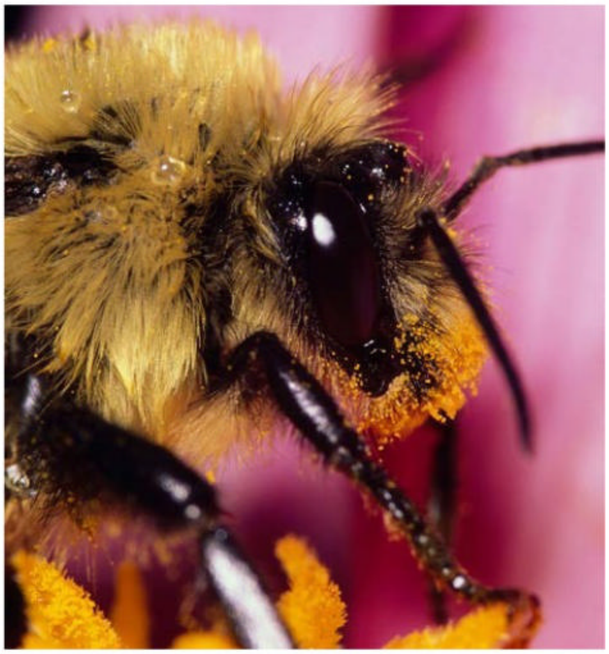
Volunteer observers played a role in this study, helping to provide data, photographing species in the field for experts to identify. An American bumblebee is shown here. Photo courtesy University of York.

At risk of extinction

The researchers assessed the extinction risk for the American bumblebee, ranking this as much higher than a federal advisory committee's most recent assessment which classified the species' extinction risk at the level of special concern. "This species is at risk of extinction and it's currently not protected in any way despite the drastic decline," says Assistant Professor Sheila Colla, an expert in bees and endangered species in York University's Faculty of Environmental Studies.

"Hopefully, now that we have assessed the extent of the decline and located where the remaining populations are, we can look more closely at threats and habitat requirements to design an effective conservation management plan so that this species does not disappear from Canada forever," adds Colla, who helped to design the study.

As bee numbers in general decline, so the risk to Canada's agricultural industry increases significantly, in the absence of pollinators such as the American bumblebee. Photo courtesy Marc Parsons/ www.shutterstock.com



Prof Colla has been studying bumblebees in Southern Ontario since the mid-2000s. This new study relies on the annual data that she and her fellow researchers have collected. The research team – led by Victoria MacPhail, Colla's doctoral student, and including a scientist from the University of Vermont – used data from three sources. They analysed Southern Ontario data from the citizen science programme, called *Bumble Bee Watch*, consisting of a collaboration of volunteers who submit bumblebee photos through a website or phone app for experts to identify.

The researchers also used the *Bumble Bees of North America* database to obtain records of bumblebee species in Ontario and Quebec dating back to the late-1800s. They used their own field survey work too, which allowed them to evaluate the status of the species within its Canadian range, using the globally-recognised International Union for the Conservation of Nature (IUCN) Red List assessment criteria.

The outcome of the study

The findings from this research have revealed that the American bumblebee's area of distribution has decreased by about 70 percent, and its relative abundance fell by 89 percent from 2007-2016, compared with 1907-2006. "This bumblebee species now has a reduced overall range," explains MacPhail. "It used to stretch from Windsor to Toronto, and all the way to Ottawa and into the Quebec area, but it is now only found in some core areas and has experienced a 37 percent decrease in its overall range."

"It's now a rare sighting in Toronto," she adds. "In terms of relative abundance, compared with other bees, you'd have to catch 1,000 bumblebees to find four of this species, and that compares to finding just 37 bees in the past. You could walk out the door and win the lottery and find it, or you could be searching for years and not find any."

This study echoes Colla's previous findings with the critically endangered rusty-patched bumblebee *(Bombus affinis)*, which was once found in Southern Ontario. Sadly, this species has not been seen in Canada for about 10 years and drastically declined towards extinction without receiving protection or conservation management. "The American bumblebee is still found in areas throughout its Canadian range and immediate action may save it from the same fate as the rusty-patched bumblebee," she says.

Further information

Victoria J. MacPhail, Leif L. Richardson, Sheila R. Colla. **Incorporating citizen science, museum specimens, and field work into the assessment of extinction risk of the American Bumble bee (*Bombus pensylvanicus* De Geer 1773) in Canada.** *Journal of Insect Conservation,* 2019; DOI: 10.1007/s10841-019-00152-y

Incredible diversity found in frogs from the Seychelles

Research scientists led by the University of Kent in the UK have uncovered hidden diversity within a type of frog found only in the Seychelles, showing that those on each island have their own distinct lineage.

The family tree of sooglossid frogs means that today's species are living descendants of those that survived the meteor strike on earth approximately 66 million years ago which led to the extinction of the dinosaurs. Their most recent common ancestor dates back some 63 million years, making them a highly evolutionarily distinct group.

There are just four species of sooglossid frog. They are the Seychelles frog *(Sooglossus sechellensis)*, Thomasset's rock frog *(So. thomasseti),* Gardiner's Seychelles frog *(Sechellophryne gardineri)* and the Seychelles palm frog *(Se. pipilodryas)*. However, recent work on their genetics led by Dr Jim Labisko from Kent's School of Anthropology and Conservation revealed that each island lineage needs to be considered as a potential new species.

Of the currently recognised sooglossid species, two (Thomasset's rock frog and the Seychelles palm frog) have been assessed as critically endangered, and the other two have endangered status in terms of the International Union for Conservation of Nature (IUCN) Red List. All four species are in the top 50 of ZSL's (Zoological Society of London) Evolutionarily Distinct, Globally Endangered (EDGE) amphibians.

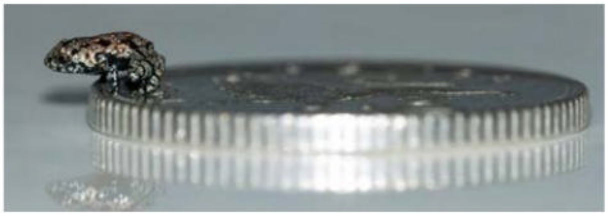
Given the Red List and EDGE status of these unique frogs, Dr Labisko and his colleagues are carrying out intensive monitoring as part of a long-term project to assess and monitor the level of risk from both climate change and disease to the endemic amphibians of the Seychelles. The project is supported by the Mohammed bin Zayed Species Conservation Fund and partners include the Island Conservation Society, the Seychelles Islands Foundation, and the Seychelles National Parks Authority.

➤ Gardiner's Seychelles frog, found on Mahé which is the largest of the Seychelles Islands.
Photo courtesy Evan Pickett

TRIOPIA
SOMALIA
NYA
airobi
Mombasa
Zanzibar
Dar es Salaam
Kilwa Masoko
Amirante Islands
Victoria
SEYCHELLES
MALDIVES

⮟ The Seychelles is a group of 115 islands - many small and uninhabited - lying off the east coast of Africa, north of Madagascar. This region is well-recognised for its unique, endemic fauna and flora.
Photo courtesy timyee/www.shutterstock.com

⮝ Caecilians are a wide-ranging but little-studied group of amphibians, with a rather worm-like appearance, as befits their subterranean lifestyle. Four species are endemic to the Seychelles.
Photo courtesy Fabio Maffei/www.shutterstock.com



A recently metamorphosed example of the Seychelles frog, measuring about 3mm (0.1in) long at this stage. Adults grow to about 8mm (0.31in) overall.

The noise of a lawnmower

Dr Labisko, who completed his doctorate on sooglossid frogs, said many of these amphibians are so small and good at hiding that the only way to observe them is by listening for their calls.

Although tiny, the sound they emit can be around 100 decibels, equivalent to the sound volume of a powerful lawnmower! The research team is therefore using sound monitors to record the vocal activity of sooglossid frogs for five minutes every hour, every day of the year, in combination with data-loggers that are sampling temperature and moisture conditions on an hourly basis.

Dr Labisko explains: "Amphibians play a vital role in the ecosystem as predators, munching on invertebrates like mites and mosquitos, so they contribute to keeping diseases like malaria and dengue fever in check. Losing them will have serious implications for human health."

As a result of this study into the frogs, the research team will also contribute to regional investigations into climate change, and local impacts in the Seychelles. Amphibians around the world are threatened by a lethal fungus known as chytrid. The monitoring of sooglossid frogs will provide crucial data on amphibian behaviour in relation to climate and disease.

If frogs are suddenly not heard in an area where they were previously, this could indicate a range-shift in response to warming temperatures, or the arrival of disease such as chytrid – significantly, the Seychelles is one of only two global regions of amphibian diversity where the disease has yet to be detected.

How monitoring frogs benefits caecilians too

The arrival of this deadly fungus would also potentially impact on a variety of other endemic Seychellois species, including the caecilians - a group of legless burrowing amphibians that are even more difficult to study than the elusive sooglossids. Researchers know that caecilians can be found in similar habitats to the frogs, so they can use the activity of the frogs and the environmental data the team is collecting to infer caecilian presence or absence in an area, and create corresponding conservation strategies as a result.

Further information

Jim Labisko, Richard A Griffiths, Lindsay Chong-Seng, Nancy Bunbury, Simon T Maddock, Kay S Bradfield, Michelle L Taylor, Jim J Groombridge. **Endemic, endangered and evolutionarily significant: cryptic lineages in Seychelles' frogs (Anura: Sooglossidae).** *Biological Journal of the Linnean Society,* 2019; 126 (3): 417 DOI: 10.1093/biolinnean/bly183

Stuck together by slug glue

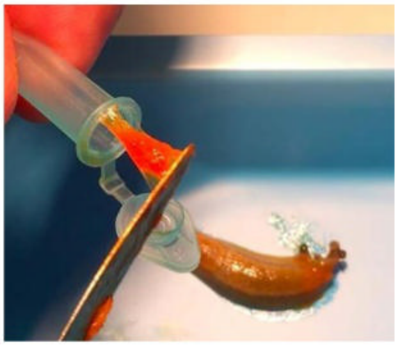
⌃ These slugs are vulnerable to attack by predators, but have evolved a unique defensive system that may have medical applications for us. Photo courtesy theLIMEs/www.shutterstock.com

The dusky arion slug *(Arion fuscus)* produces a defensive glue that fouls up the mouthparts of any would-be predator. New research is revealing more about how this remarkable adhesive achieves its strong sticking power and flexibility, with the aim of utilising this knowledge for medical purposes.

"Typical sutures like staples and stitches often lead to scarring and create holes in the skin that could increase the chance of infection after surgery," explains researcher Rebecca Falconer, based at Ithaca College in New York State. "Understanding the roles of adhesive proteins in the slug glue would aid in the creation of a medical adhesive that can move and stretch, while still retaining its strength and adhesiveness."

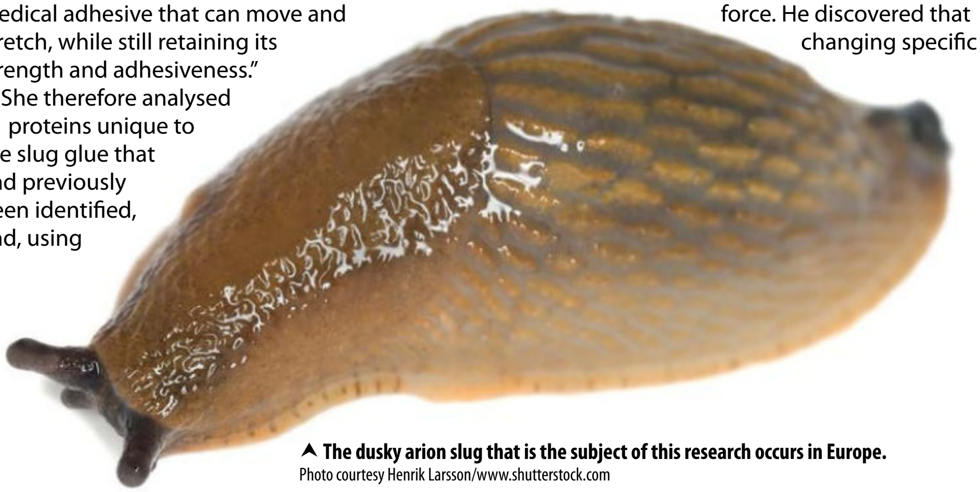
She therefore analysed 11 proteins unique to the slug glue that had previously been identified, and, using so-called 'recombinant' DNA technology, she was able to produce abundant amounts of each protein for analysis. The techniques that she developed could also be used to reproduce these proteins for a man-made glue. The analysis revealed that some of these proteins tend to bind to themselves or with other proteins to form a three-dimensional network, and this is what contributes to the way that the glue works.

Her colleague Christopher Gallego-Lazo carried out a separate study which focused on understanding the double network structure that makes the slug glue highly deformable but able to withstand large amounts of force. He discovered that changing specific chemical bonds within the slug glue's protein network modified the glue's strength. These bonds can be reformed naturally, enabling the glue to deform while maintaining its strength.



⌃ Researchers are studying how slug glue achieves its strong sticking power and flexibility, in the hope of creating better medical adhesives. Their work was presented at an Experimental Biology meeting held recently. Photo courtesy Rebecca Falconer, Ithaca College.

"Few studies on biological adhesives have identified the exact nature of the bonds holding the glue together," he explains. "This knowledge can guide the development of an organic synthetic adhesive that would reduce the risk of infection and scarring, compared with stitches and staples, and could be applied rapidly and simply."



⌃ The dusky arion slug that is the subject of this research occurs in Europe.
Photo courtesy Henrik Larsson/www.shutterstock.com

Lizard lays eggs then gives birth to live young

In a world first, researchers at the University of Sydney have observed a normally live-bearing Australian lizard lay three eggs and then weeks later, give birth to a live baby from the same pregnancy. This is the first time that such an event has been documented in a single litter of vertebrate offspring.

The lizard in question is the three-toed skink (*Saiphos equalis*). It is one of only a handful of rare so-called “bimodally reproductive” species, in which some individuals lay eggs and others give birth to live babies. But up until now, no vertebrate has ever been observed to do both in one litter. “It is a very unusual discovery,” admits Dr Camilla Whittington, from the School of Life and Environmental Sciences and Sydney School of Veterinary Science at the University of Sydney.

Differing reproductive habits

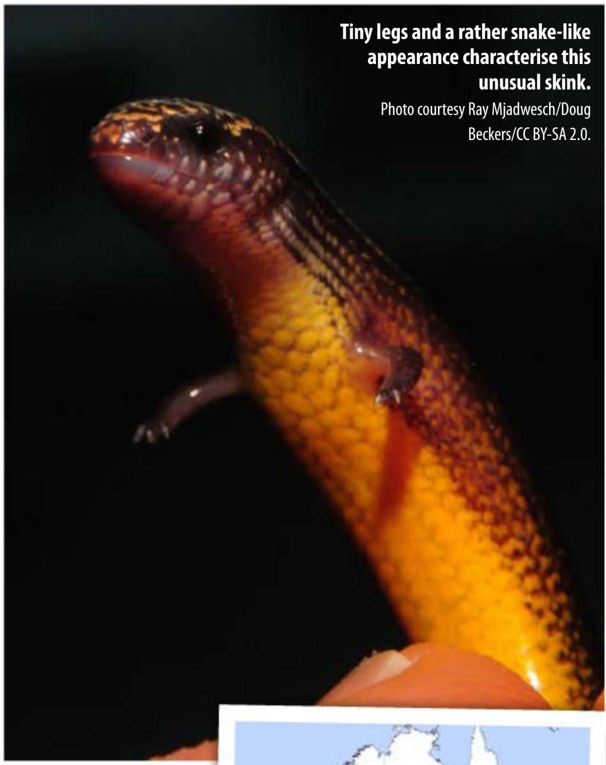
The three-toed skink is native to the east coast of Australia. In the northern highlands of New South Wales, the animals normally give birth to live young, but those living in and around Sydney lay eggs. “We were studying the genetics of these skinks when we noticed one of the live-bearing females lay three eggs,” Dr Whittington explains. “Several weeks later, she gave birth to another baby. Seeing that baby was a very exciting moment!”

There are at least 150 evolutionary transitions from egg-laying to live-bearing in vertebrates, according to Dr Whittington, who led the study alongside Dr Melanie Laird, a postdoctoral researcher at the University of Otago, and Emeritus Professor Mike Thompson.

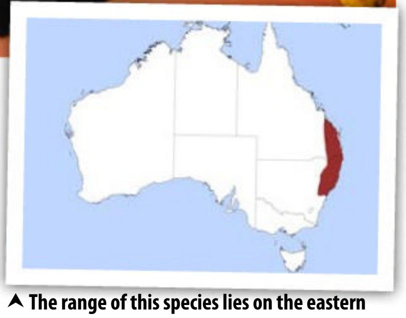
“The earliest vertebrates were egg-layers, but over thousands of years, developing embryos in some species were held inside the body for longer, until some animals began to give live birth,” she adds. “People mostly think about humans and other mammals giving birth but there are many species of reptile that give birth too.”

Learning more about live birth

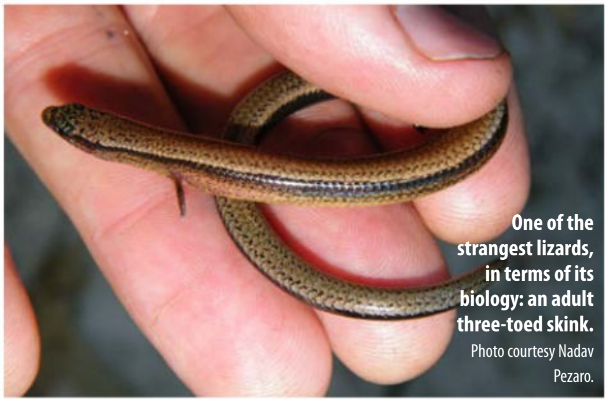
Dr Whittington said that the unusual observation of both egg-laying and live birth in a single litter shows that the three-toed skink is an ideal model for understanding pregnancy. “It makes Australia one of the best places in the world to study the evolution of live birth, because we can watch evolution in action,” she says. “Put into the context of evolutionary biology, being able to switch between laying eggs and giving birth to live offspring could allow animals to hedge their bets according to environmental conditions.”



Tiny legs and a rather snake-like appearance characterise this unusual skink. Photo courtesy Ray Mjadwesch/Doug Beckers/CC BY-SA 2.0.



^ **The range of this species lies on the eastern side of the continent.** Map courtesy Nrg800.



One of the strangest lizards, in terms of its biology: an adult three-toed skink. Photo courtesy Nadav Pezaro.

This new observation helps make the three-toed skink, which looks rather like a baby snake with tiny legs, one of the “weirdest lizards in the world”, according to Dr Whittington. Further research into this small lizard, which clearly seems to occupy a grey area between live birth and egg-laying, will help to determine how and why species make major reproductive leaps.

Dr Camilla Whittington seen here, holding a different species of lizard known as Cunningham’s skink, is part of the team that has recorded this discovery.

Further information

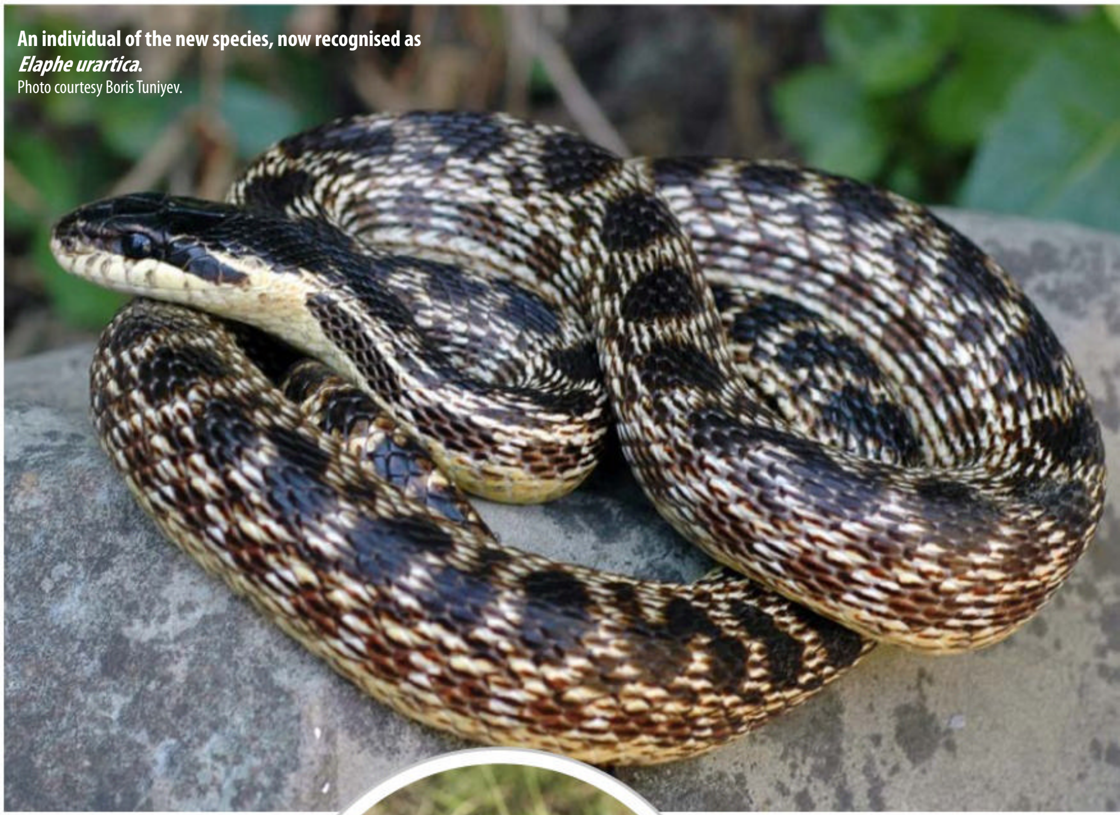
Melanie K. Laird, Michael B. Thompson, Camilla M. Whittington. **Facultative oviparity in a viviparous skink (*Saiphos equalis*).** *Biology Letters*, 2019; 15 (4): 20180827 DOI: 10.1098/rsbl.2018.0827

New European snake species discovered

An international team of scientists has identified a new species of snake along with its range, which extends to Turkey, Azerbaijan, Armenia, Georgia, Iraq, Iran, and Russia including a small region in the far eastern corner of Europe. Based on the genetic and morphological data that they collected, the researchers were able to say that the blotched rat snake (*Elaphe sauromates*) is actually comprised of two different species and includes a cryptic species - meaning one that looks similar to another, but is genetically different.

The scientific name of '*Elaphe sauromates*' refers to the Sarmatians, a confederation of nomadic peoples who inhabited vast areas of the recent range of the blotched rat snake's habitat, between the 5th century BC and the 4th century AD. The newly-discovered species has now been named as *Elaphe urartica*, after the old kingdom of Urartu.

This kingdom, forgotten for over a thousand years, flourished between the 9th and 6th centuries BC in the area of today's Armenian Highlands, centred around Lake Van in Turkey, where this new snake species occurs. The name was chosen out of respect for the original scientific name of the blotched rat snake proposed by Peter Simon Pallas, the famous Prussian natural historian of the 19th century.



An individual of the new species, now recognised as *Elaphe urartica*. Photo courtesy Boris Tuniyev.

Rarely seen

According to Daniel Jablonski and David Jandzik, lead scientists of the project who are based at the Comenius University in Bratislava, Slovakia, these snakes are very rarely observed in the field and are mostly distributed in geopolitically complicated regions. As a result, the material for their study had been collected for over 17 years, and required a broad international collaboration.

The new snake species is a member of the large-bodied snakes forming the genus *Elaphe*. A number of different rat snakes are well-represented in the hobby of course, although many of the previously recognised species have now been transferred into other genera. The discovery and analysis of the biogeographical history of this new snake fills in an important piece of the jigsaw in understanding the development of this group of reptiles in Eurasia.

⮝ There are very obvious differences in appearance between individuals of what used to be known as *Elaphe sauromates*, with some individuals being conspicuously less heavily blotched than others. Photo courtesy Tiberiu Sahlean/www.shutterstock.com

⮜ The area around Lake Van in Turkey is central to the region where this new species can be found. Photo courtesy WitR/www.shutterstock.com

Further information

Daniel Jablonski, Oleg V. Kukushkin, Aziz Avcı, Sabina Bunyatova, Yusuf Kumlutaş, Çetin Ilgaz, Ekaterina Polyakova, Konstantin Shiryaev, Boris Tuniyev, David Jandzik. **The biogeography of *Elaphe sauromates* (Pallas, 1814), with a description of a new rat snake species.** *PeerJ*, 2019; 7: e6944 DOI: 10.7717/peerj.6944

Long-standing snake mystery

Herpetologists at The University of Texas at Arlington (UTA) have now described a previously unknown species of snake that was discovered more than four decades ago - lodged inside the stomach of another snake!

The new snake has been named *Cenaspis aenigma*, which translates from Latin as "mysterious dinner snake". It has been named by Jonathan Campbell, UTA professor of biology; Eric Smith, UTA associate professor of biology; and Dr Alexander Hall. The researchers' work identifies *Cenaspis* not only as a new species but also as forming an entirely new genus.

A single individual

The only specimen known to date, however, was found during 1976 in the stomach of a Central American coral snake — a species that is known to eat smaller snakes — by palm harvesters in the southern Mexico state of Chiapas. The mysterious specimen, measuring 25cm (10in) long, was subsequently preserved in a museum collection. Amazingly, a live specimen of this snake has never been found over the past four decades, in spite of intensive searches for it.

"This small snake was now obtained over 40 years ago, and the report of its discovery has been a long time in coming," admit the scientists. "We were optimistic that additional specimens might be secured, but after at least a dozen more trips into the region spanning several decades, we have been unrewarded."

It was thanks to a Central American coral snake (*Micrurus nigrocinctus*) that the new species came to scientific attention. Photo courtesy Elliotte Rusty Harold/www.shutterstock.com

Unique characteristics

Cenaspis has several distinctive features that defy placing it in any known genus and clearly distinguishes it from all known genera. These include undivided subcaudal scales, or enlarged plates on the underside of its tail; a lack of spines and the presence of cup-like structures called calyces on its hemipenes, which are the paired male reproductive organs found in snakes and lizards. The shape of its skull is another of its highly distinctive characteristics.

The first two of those features are not found in any other known snake in the family Colubridae in the Western Hemisphere. This is in spite of the fact that colubrids represent the largest snake family and include just over 51 percent of all known living snake species.

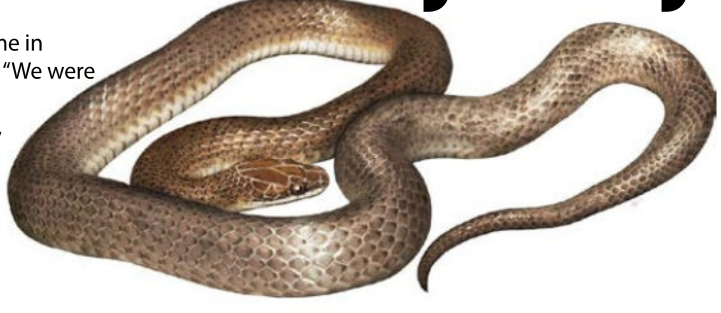
Utilising the vast resources of UTA's Amphibian and Reptile Diversity Research Center for comparative purposes, the researchers made CT scans of dozens of specimens of snakes. The biologists believe that due to some of the specimen's physical features, Cenaspis is likely to be a burrowing snake that feeds on insects and spiders. Campbell believes that it is not extinct but has eluded capture most probably as a result of its burrowing lifestyle and elusive habits.

Call for a sanctuary

Prof Campbell has proposed that because of the snake's unique nature, the Chiapas highlands area of southern Mexico where it was found all those years ago should be considered for protected status, so that in addition, more unknown species which might be discovered there will not face possible extinction.

Professor Campbell is one of the world's most pre-eminent herpetologists and has spent over 45 years discovering, studying and describing the herpetofauna of North, Central and South America, as well as the Caribbean and West Africa. He earned a doctorate in systematics and ecology from the University of Kansas in 1982 and came to UTA in 1983.

He has overseen the tremendous growth of UTA's Amphibian and Reptile Diversity Research Center from a modest collection into one of the top centres for herpetology in the world, with one of the largest assemblages of specimens anywhere. His work has already led to the description of more than 100 new species, some of which were on the brink of becoming extinct without ever being known to science.



A reconstruction of the snake that was discovered, with both the species and its genus being previously unknown to science. Artwork courtesy The University of Texas at Arlington.

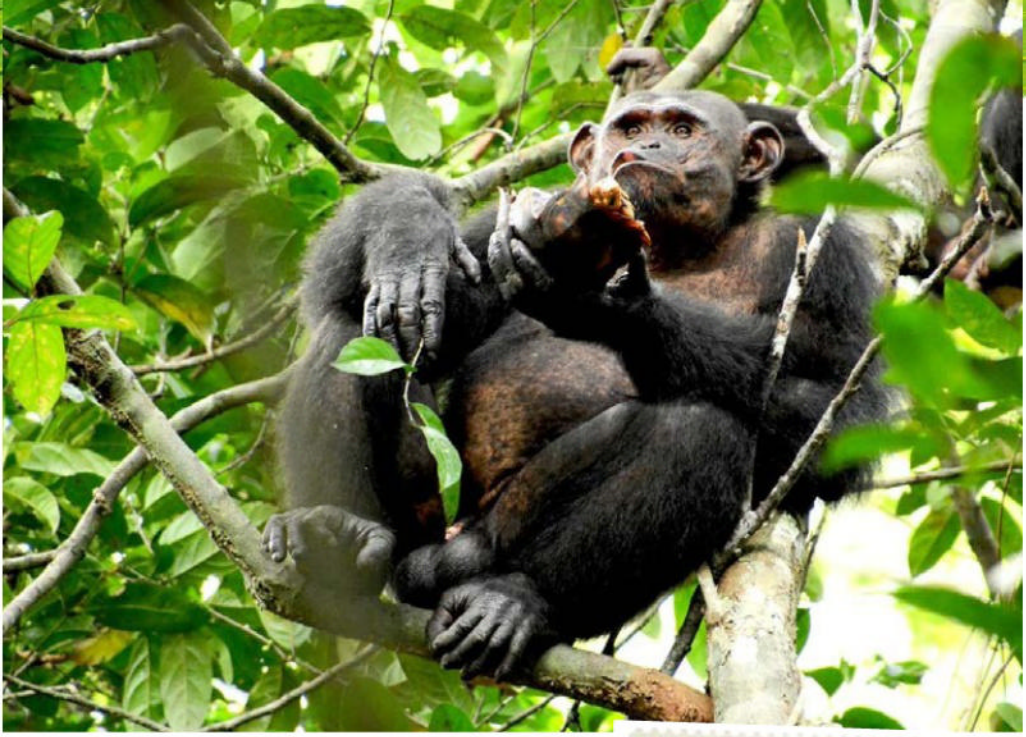
The researchers who have been investigating the mystery: l-r Jonathan Campbell, UTA professor of biology; Eric Smith, UTA associate professor of biology; and Dr Alexander Hall. Photo courtesy UTA.

Further information

Jonathan A. Campbell, Eric N. Smith, Alexander S. Hall. **Caudals and Calyces: The Curious Case of a Consumed Chiapan Colubroid.** *Journal of Herpetology*, 2018; 52 (4): 458 DOI: 10.1670/18-042

The remains of the new species were discovered by palm harvesters there. Photo courtesy Dieter Bauwens/www.shutterstock.com

Tortoises hunted



A chimpanzee at Loango National Park in Gabon feeding on tortoise meat. Photo courtesy Erwan Theleste.

It appears that hingeback tortoises, notably the forest hingeback (*Kinixys erosa*), face a previously unrecognised hunting threat, at least in one part of their range. "We have known for decades that chimpanzees feed on meat from a variety of animal species, but until now, the consumption of reptiles has not been observed," explains Tobias Deschner, a primatologist at the Max Planck Institute for Evolutionary Anthropology.

"What is particularly interesting is that with the tortoises, the chimpanzees use a percussive technique that they normally employ to open hard-shelled fruits, so as to gain access to the meat of an animal that is almost inaccessible to any other predator," he adds.

The researchers studied the behaviour of chimpanzees belonging to the Rekambo community. They observed 38 prey events by 10 different chimpanzees during the dry season, which is also a period when other preferred food such as fruits is abundant.

"Sometimes, younger animals or females were unable to crack open the tortoise on their own. They then regularly handed the tortoise over to a stronger male who cracked the tortoise's shell open and shared the meat with all the other individuals present," says Simone Pika, who is a cognitive scientist at the University of Osnabrück. These particular tortoises are especially well protected, even possessing a hinged shell that should normally deter predation.

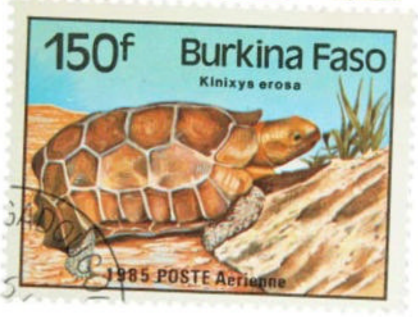
Leftovers from dinner

There was one exceptional case in which an adult male, who was on his own, cracked a tortoise, ate half of it up while sitting in a tree and then tucked the rest of it in a tree fork. He climbed down, built his nest in a nearby tree and came back the next morning to retrieve the leftovers and continue to feast on them for breakfast.

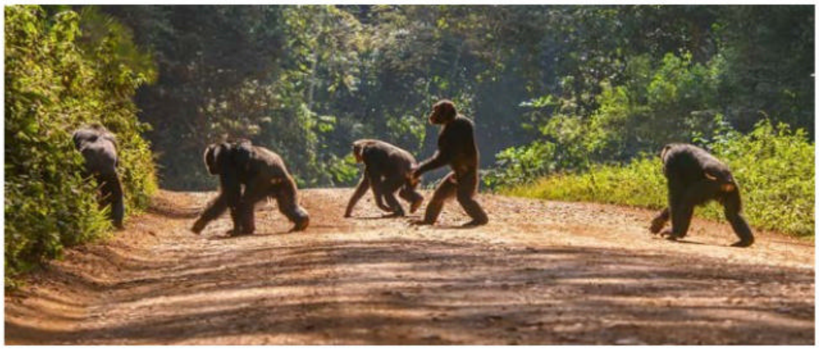
"This indicates that chimpanzees may plan for the future," says Pika. "The ability to plan for a future need, such as for instance hunger, has so far only been shown in non-human animals in experimental and/or captive settings. Many scientists still believe that future-oriented cognition is a uniquely human ability. Our findings thus suggest, however, that even after decades of research, we have not yet grasped the full complexity of chimpanzees' intelligence and flexibility."

Adaptability rules!

Deschner continues: "Wild chimpanzee behaviour has been studied now for more than 50 years and at more than 10 long-term field sites all across tropical Africa. It is fascinating that we can still discover completely new facets of the behavioural repertoire of this species as soon as we start studying a new population."



The forest hingeback tends to be dull reddish-brown in colour, and is relatively small in size. It is found in tropical forests and also marshy areas in central and western parts of Africa. Photo courtesy EtiAmmos/www.shutterstock.com



Chimpanzees will encounter tortoises when foraging on the ground, and especially in open areas. Photo courtesy CherylRamalho/www.shutterstock.com

The authors further emphasise the importance of non-human primate field observations to inform theories of our own development. "As one of our closest living relatives, the study of chimpanzee behaviour is a window into our own history and evolution," explains Pika.

But the time to gain insight may be short, especially as different populations display different behaviours. "In order to prevent this window from closing once and for all, we need to do whatever we can to secure the survival of these primates in their natural habitats across Africa," Deschner adds.

Further information

Simone Pika, Harmonie Klein, Sarah Bunel, Pauline Baas, Erwan Théleste, Tobias Deschner. **Wild chimpanzees (*Pan troglodytes troglodytes*) exploit tortoises (*Kinixys erosa*) via percussive technology.** *Scientific Reports*, 2019; 9 (1) DOI: 10.1038/s41598-019-43301-8

Are otters now threatening amphibian populations?

An otter plunges into water in the hope of grabbing prey. Amphibians can be caught in shallow water, often revealing their presence by making a noise, and so drawing the otter's attention to them. Photo courtesy Alec Taylor/www.shutterstock.com

The Eurasian otter typically eats fish, but amphibians, which are in global decline, are also part of its diet, especially when fish are scarce. This is particularly relevant now, partly because otters are staging a comeback in many areas of their former range in Europe, particularly in Britain.

In the case of this study, researchers identified bones of amphibians in otter faeces from southern Italy to determine which types of amphibians are typically eaten. They also reviewed 64 studies which had focused of the diets of this particular mammal, and noted that typically, about 12 percent of their prey was made up of amphibians.

Predation of amphibians was found to increase with longitude and was highest in the Alpine biogeographical region during winter and spring. Also, 28 amphibian species (35 percent of European species) were eaten by otters.

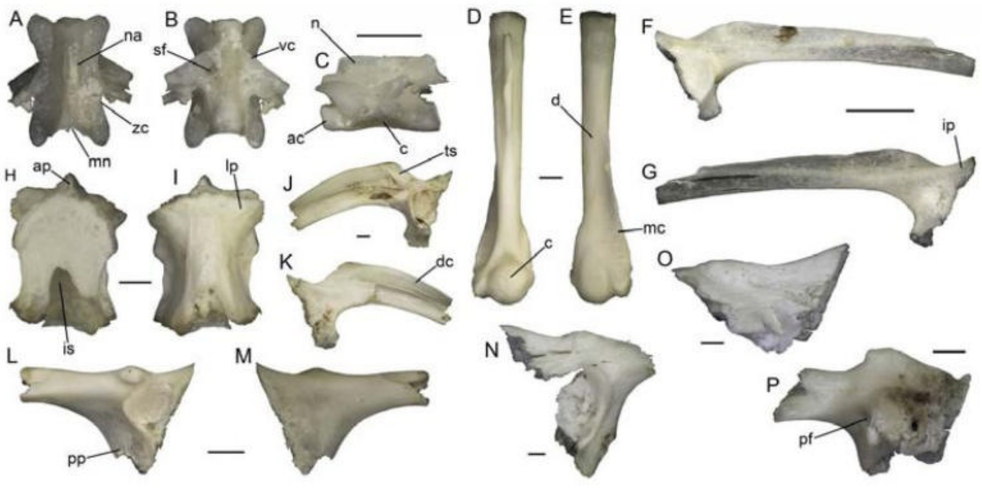
Following their analyses in southern Italy, the investigators identified 355 individuals belonging to at least seven amphibian taxa. They also concluded that when feeding on frogs and toads, otters are more likely to take the noisy males than the quieter females.

⮝ **It has also been discovered that otters prey more on male frogs and toads, which attract attention to their position by calling.** Photo courtesy Suravikina Anastasiia/www.shutterstock.com

Impacts on the food chain

The findings suggest that amphibians are a more significant part of the otter's diet than commonly perceived. While this may constitute a threat to small populations of endemic amphibians, their global decline is also likely to have consequences for the survival of otters wherever fish resources have been depleted by overfishing and pollution.

"We knew that amphibians may represent a major food source for otters in the Mediterranean area, but I admit we were amazed and impressed to discover how great the diversity of this resource could be," says researcher Dr. Alessandro Balestrieri from the University of Milan in Italy.



⮝ **Bone fragments, used in the identification of amphibian prey, from the faeces of the Eurasian otter.** Photo courtesy Dr Balestrieri.

Further information

Giorgio Smiroldo, Andrea Villa, Paolo Tremolada, Pasquale Gariano, Alessandro Balestrieri, Massimo Delfino. **Amphibians in Eurasian otter *Lutra lutra* diet: osteological identification unveils hidden prey richness and male-biased predation on anurans**. *Mammal Review*, 2019; DOI: 10.1111/mam.12155

Snake bites affected by rain

Photo courtesy Joe McDonald/www.shutterstock.com

Hikers and trail runners be warned: rattlesnakes and other venomous reptiles may bite more people during rainy years than in seasons wracked by drought, according to a North American new study. This research, which was led by Caleb Phillips of the University of Colorado (CU) Boulder and Grant Lipman of the Stanford University School of Medicine, examined 20 years of snakebite data from across California. Their findings contradict a popular theory among many wilderness health professionals that drought might increase snake bites by pushing the reptiles into the open where they are more likely to encounter people.

Instead, the group discovered that for every 10 percent increase in rainfall over the previous 18 months, cases of snake bites spiked by 3.9 percent in California's 58 counties. The results could have implications for efforts to prevent and treat dangerous encounters between humans and snakes, especially as climate patterns shift across the western United States.

Extending the survey

"This study shows a possible unexpected, secondary result of climate change," says Phillips, who is an adjunct assistant professor in CU Boulder's Department of Computer Science. "We probably need to take climatological changes into account when we coordinate systems that may seem unrelated like planning how we distribute antivenin supplies or funding poison control centres."

Phillips and his colleagues suspect that the reason for the surge in snake bites during wet years may come down to snake food. Mice and other rodents, which are the main prey of rattlesnakes, flourish in rainy years, and that might give snakes a boost, encouraging their hunting instincts and causing them to become more active.

The aim now is to find out if the same trends appear outside of California. The state of Colorado is home to three closely related species of venomous reptiles, in the guise of the prairie, western and massasauga rattlesnakes. Bites from these snakes rarely kill humans, but tragedy can nevertheless strike on occasions, as when Colorado triathlete Dan Hohs, for example, died from a rattlesnake bite in 2017.

BEWARE
Rattlesnakes!

◀ **A rattlesnake warning sign on a sunny day - but wet periods may be more dangerous for bites.**
Photo courtesy Checubus/www.shutterstock.com

Concerns about climate change

The researchers wondered how climate change might influence the frequency of such encounters. They pored through 5,365 cases of rattlesnake bites reported to the California Poison Control System between 1997 and 2017. The team then compared those cases with a range of other information, including climate data from NASA and drought records from the National Drought Mitigation Center.

▲ **Rattlesnake Canyon in Colorado; the researchers now want to discover if their climatic findings apply in this state too.**
Photo courtesy Alberto Loyo/www.shutterstock.com

What the group found was surprising, because when Californian counties experienced drought, recorded cases of snake bites dropped off. Those incidences hit record low levels statewide in 2015 and 2016 when California was in the middle of a historic dry spell. Research in Colorado and other parts of the United States suggests that the impact of warming temperatures on rainfall patterns will be a mixed bag, with some regions experiencing more severe storms and others seeing drier weather.

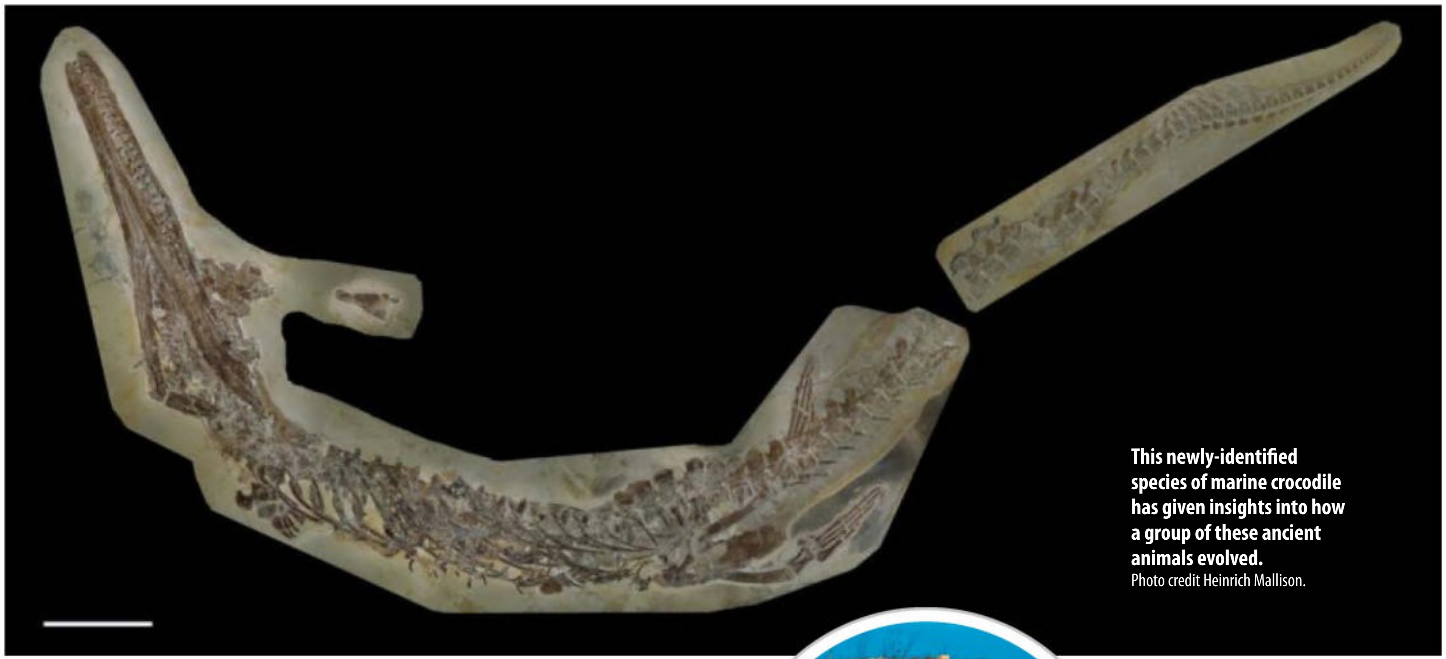
Phillips, who is himself an avid trail runner and trained wilderness first responder, urges fellow outdoor enthusiasts to stay calm. He advises: "If you encounter a rattlesnake, don't pick a fight with it, and it won't pick a fight with you."

◀ **The western is one of three species of rattlesnake found in Colorado.** Photo courtesy Max Allan/www.shutterstock.com

Further information

Caleb Phillips, Grant S. Lipman, Hallam Gugelmann, Katie Doering, Derrick Lung. **Snakebites and climate change in California, 1997–2017**. *Clinical Toxicology*, 2018; 1 DOI:10.1080/15563650.2018.1508690

Jurassic crocodile sheds light on family tree



This newly-identified species of marine crocodile has given insights into how a group of these ancient animals evolved. Photo credit Heinrich Mallison.

An ancestor of today's crocodiles belonged to a group of animals that developed a tail fin and paddle-like limbs for life in the sea, and so actually resembled modern-day dolphins more than crocodiles. These slender animals, which fed on fast-moving prey such as squid and small fish, lived during the Jurassic era, about 150 million years ago, in shallow seas and lagoons in what is now Germany. Related species have previously been found in Mexico and Argentina, but this is the first discovery of the group made in Europe.

Quarry discovery

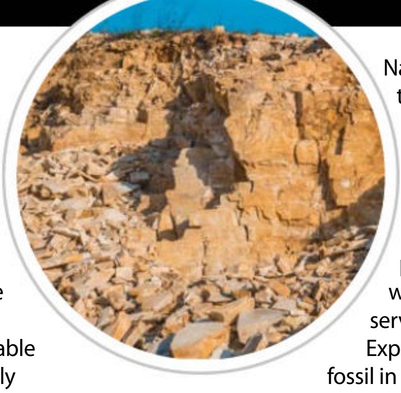
An international team of scientists, including researchers from Germany and the University of Edinburgh, identified the new species from a remarkably well-preserved skeleton. The fossil was discovered during 2014 in a quarry near the town of Bamberg in Bavaria, Germany by a team from the Naturkunde-Museum Bamberg, where it is now housed. This new species, known to science as *Cricosaurus bambergensis*, was actually named after the town. When researchers compared the fossil with those from other museum collections, they were able to confirm that it was a previously unknown species.

Anatomical features

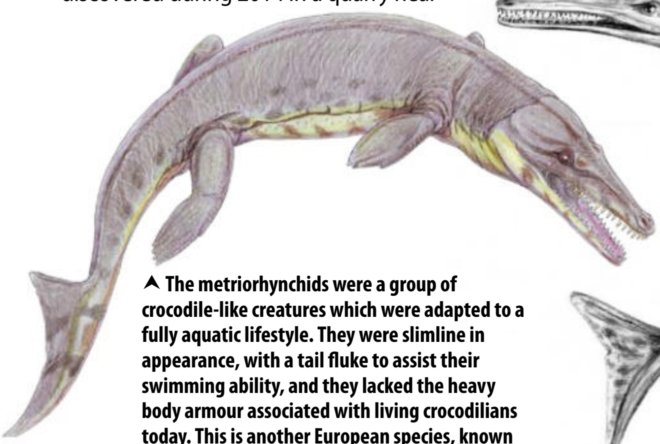
The skeleton has several distinguishing features in its jaws, the roof of its mouth and its tail, some of which are unique and have not been documented before. According to Sven Sachs, from the Naturkunde-Museum Bielefeld, this study revealed peculiar features on the palate that have not previously been described in any other fossil crocodilian, in the form of two depressions which are separated by a pronounced bar. It is not clear what purpose these depressions served.

Experts created digital images of the fossil in high resolution, to enable further research. They expect the fossil will aid better understanding of a wider family of ancient animals, known as metriorhynchids, to which this species belonged.

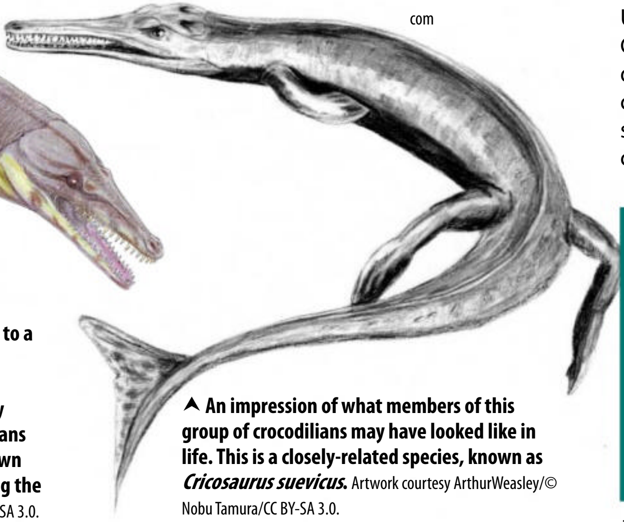
"The rock formations of southern Germany continue to give us fresh insights into the age of dinosaurs," explains Dr Mark Young, from the University of Edinburgh's School of GeoSciences. "These rock layers were deposited at a time when Europe was covered by a shallow sea, with countries such as Germany and the UK being a collection of islands."



⮝ Bavaria's quarries have yielded a host of spectacular and previously unknown fossils over the years, which formed when the area was largely submerged by sea. Photo courtesy Martin Erdniss/www.shutterstock.com



⮝ The metriorhynchids were a group of crocodile-like creatures which were adapted to a fully aquatic lifestyle. They were slimline in appearance, with a tail fluke to assist their swimming ability, and they lacked the heavy body armour associated with living crocodilians today. This is another European species, known as *Suchodus durobrivense*, which lived during the late Jurassic. Artwork courtesy Dmitry Bogdanov/CC BY-SA 3.0.



⮝ An impression of what members of this group of crocodilians may have looked like in life. This is a closely-related species, known as *Cricosaurus suevicus*. Artwork courtesy ArthurWeasley/© Nobu Tamura/CC BY-SA 3.0.

Further information

Sven Sachs, Mark Young, Pascal Abel, Heinrich Mallison. **A new species of the metriorhynchid crocodylomorph *Cricosaurus* from the Upper Jurassic of southern Germany**. *Acta Palaeontologica Polonica,* 2019; 64 DOI: 10.4202/app.00541.2018

Killer spiders

The stuff of nightmares for some people has now been confirmed as reality, as a University of Michigan-led (U-M-led) team of biologists has documented 15 disturbing predator-prey interactions in the Amazon rainforest. These relate to instances of arthropod predators—mostly large spiders along with a few centipedes and a giant water bug—preying on vertebrates such as frogs and tadpoles, plus lizards and snakes. One of the most dramatic cases that was observed was of a dinner plate-sized tarantula dragging a young opossum across the forest floor.

"This is an under-appreciated source of mortality among vertebrates," says U-M evolutionary biologist Daniel Rabosky. "A surprising number of deaths amongst small vertebrates in the Amazon are likely to be due to arthropods such as big spiders and centipedes."

▲ **It is well-known that tarantulas will prey on fellow invertebrates, like this large cicada in the Peruvian Amazon region, but there is now clear evidence they prey regularly on a varied range of vertebrates here as well.** Photo courtesy Ryan M. Bolton/www.shutterstock.com

An area with high biodiversity

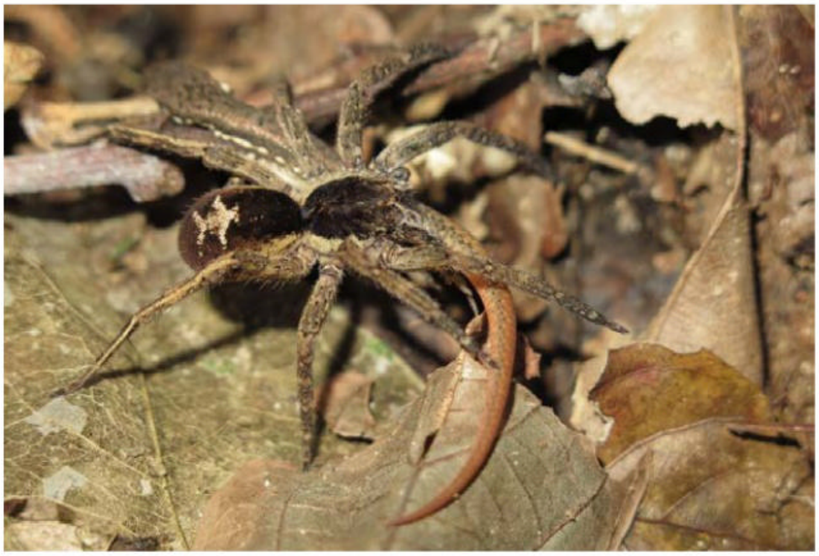
Once or twice a year, Rabosky leads a team of U-M researchers (ranging from faculty members to undergraduates) as well as international collaborators on a month-long expedition to the Los Amigos Biological Station in the remote Madre de Dios region of southeastern Peru. "We were pretty ecstatic and shocked, and we couldn't really believe what we were seeing. We knew we were witnessing something pretty special, but we weren't aware that it was the first observation until after the fact," he admits.

The study site, in lowland Amazon rainforest near the Andean foothills, is in the heart of one of the most diverse ecosystems on the planet. The team's main research focus is the ecology of reptiles and amphibians, but over the years, the scientists have witnessed and documented numerous interactions between arthropod predators and vertebrate prey. "We kept recording these events, and then we realised that we had enough observations to put them together in a paper," explains Rabosky.

Spiders rule!

These arachnids are among the most diverse arthropod predators in the tropics, and previous reports of spider predation in the Amazon include prey from all major vertebrate taxonomic groups: fish, amphibians, reptiles, birds and mammals. But knowledge of these interactions remains limited, especially given the diversity of vertebrate prey and potential arthropod predators in such varied tropical communities. The observations in this case stem from a period of some nine years.

"These events offer a snapshot of the many connections that shape food webs, and they provide insights into an important source of vertebrate mortality that appears to be less common outside the tropics," says Rudolf von May, a postdoctoral researcher in Rabosky's lab. "Where we do this research there are about 85 species of amphibians—mostly frogs and toads—and about 90 species of reptiles. So considering that there are hundreds of invertebrates that potentially prey upon vertebrates, the number of possible interactions between species is huge, and we are highlighting that fact."

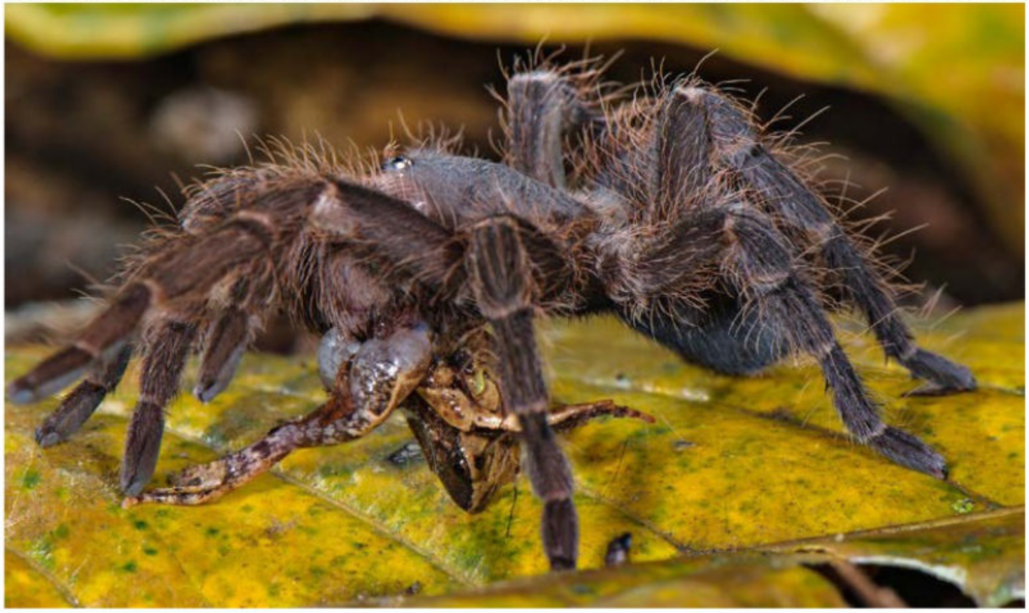


◀ **A wandering spider (Ctenidae) preying on a subadult Eigenmann's prionodactylus (*Cercosaura eigenmanni*) lizard.** Photo courtesy Mark Cowan.

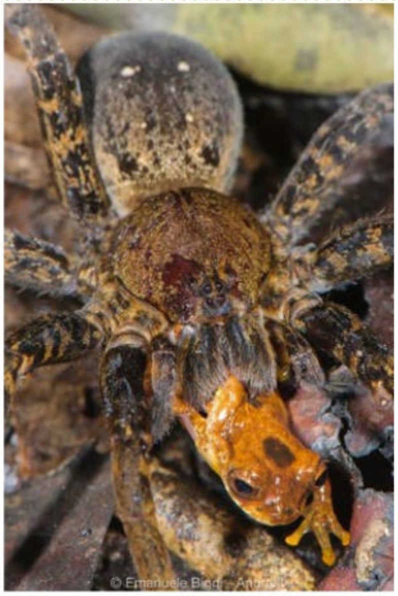
Night-time hunting

In addition to the Los Amigos Biological Station, other observations were made at the Villa Carmen Biological Station, also in Peru's Madre de Dios region, and at the Madre Selva Research Station in the Loreto region of northern Peru. Nearly all of the sightings were made at night, when the arthropod predators are most active. During their night-time surveys, team members walk slowly through the forest with flashlights and headlamps, in single file, scanning the forest and listening intently.

It was during one of those nocturnal surveys that U-M researcher Michael Grundler and two companions were attracted by some noise in the form of



⮝ **A fishing spider (genus *Thaumasia*) has seized this tadpole from a pond.** Photo © Emanuele Biggi, Anura.it



⮝ **A wandering spider (genus *Ancylometes*) in the lowland Amazon rainforest preying on a tree frog (*Dendropsophus leali*). This spider is a member of the Ctenidae group.** Photo © Emanuele Biggi, Anura.it

scrabbling in the leaf litter. "We looked over and saw a large tarantula on top of an opossum," he recalls. "The opossum had already been grasped by the tarantula and was still struggling weakly at that point, but after about 30 seconds, it had stopped kicking."

The tarantula was the size of a dinner plate, and the young mouse opossum was about the size of a tennis ball. Maggie, Grundler's sister, pulled out her cell phone and shot photos and some video. Later, an opossum expert at the American Museum of Natural History confirmed they had captured the first documented case of a large mygalomorph spider preying on an opossum. The infraorder Mygalomorphae is a group of mostly heavy-bodied, stout-legged spiders that includes tarantulas.

"We were pretty ecstatic and shocked, as we couldn't really believe what we were seeing," says Michael Grundler. "We knew we were witnessing something pretty special, but we weren't aware that it was the first recorded observation of this type until after we started looking into it."

Hunting techniques

Most predatory arthropods rely on specialised body parts and venom to capture and paralyse vertebrate prey. These adaptations include modified jaws, enlarged beaks and massive fangs. Some groups have evolved dozens of venom proteins that are injected during prey capture.

Other predator-prey interactions that have been recorded by the team include several examples of large spiders of the family Ctenidae preying on frogs and also a lizard. Most of the predation events that have been documented involve spiders, and most of those were ctenids, which are commonly known as wandering spiders.

Ctenid spiders are sit-and-wait predators that hunt at night and use specialised hairs on their legs to detect air vibrations and sense the direction of prey. Their principal eyes are responsible for object discrimination, while their secondary eyes detect motion.

More examples

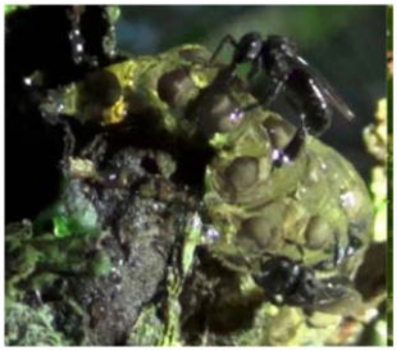
There was also a case of a large scolopendrid centipede consuming a live Catesby's snail-eating snake, and another centipede eating a dead coral snake that it had decapitated. "Coral snakes are very dangerous and can kill humans," says U-M's Joanna Larson. "To see one taken down by an arthropod was very surprising. Those centipedes are terrifying animals, actually."

"One of the coolest things about working in Peru is the sheer number of species that you encounter on a daily basis simply by walking in the forest," adds Larson, who studies the evolution of diet in frogs. "Every day you see something new and exciting."

"An offshoot of our work is this collection of odd natural history events that we've witnessed involving arthropod predators and vertebrates," she continues. "I've not reached the level of being grossed out by any of it yet. And I'm sure Peru will have much more to offer, in terms of new findings."

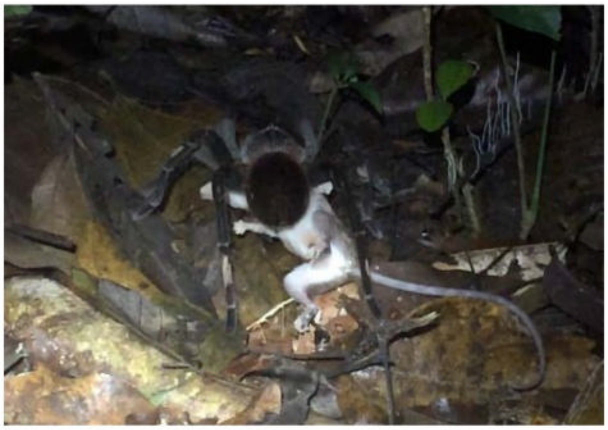
Further information

Rudolf von May, Emanuele Biggi, Heidy Cárdenas, M. Isabel Diaz, Consuelo Alarcón, Valia Herrera, Roy Santa-Cruz, Francesco Tomasinelli, Erin P. Westeen, Ciara M. Sánchez-Paredes, Joanna G. Larson, Pascal O. Title, Maggie R. Grundler, Michael C. Grundler, Alison R. Davis Rabosky, Daniel L. Rabosky. **Ecological interactions between arthropods and small vertebrates in a lowland Amazon rainforest.** *Amphibian & Reptile Conservation*, 2019; 13(1)



⮝ **Stingless bees (*Trigona* species) seen preying on a clutch of tree frog eggs above a flooded area on the forest floor.** Photo courtesy Rudolf van May.

⮟ **A tarantula (genus *Pamphobeteus*) preying on a mouse opossum (genus *Marmosops*).** Photo courtesy Maggie Grundler.



Night light not recommended for amphibians

Light at night might be convenient for humans, but it's having a detrimental effect on amphibian populations, according to new research from Binghamton University, State University of New York. "Research on the effects of light pollution has revealed that it's now difficult to find any place on Earth that is not affected by even minimal light pollution," says Jessica Hua, Assistant Professor of Biological Sciences at the university.

"We recognised a gap in the research and realised that not much was known about how light pollution can impact amphibians. Since amphibians are sensitive to environmental changes, they make great models for studying how pollution of any type can impact other species."

Laboratory findings

Hua and her colleagues exposed wood frogs to a control situation and two anthropogenic (man-made, artificial) light conditions, in the form of intensified daytime illuminance and artificial light at night (ALAN). They found that both the intensified daytime illuminance treatments and the ALAN treatment decreased hatching success of their spawn. Tadpoles that were reared in the ALAN treatment, furthermore, were larger, less active, more sensitive to road salt pollution and had more parasites.

"Overall, I think the main thing we learned from this study is that exposure to light at night has the potential to make amphibians more susceptible to the effects of additional stressors, like road salt and parasites," says fellow researcher Gracen Shidemantle. "This is concerning since these are common stressors that many amphibians have to cope with. The light at night on its own might not have too much of a negative effect but since wildlife rarely encounter just one stressor in their natural habitat, the combination of light pollution with additional stressors may have negative impacts on amphibian populations."

⮝ **Wood frogs were chosen as the subject for the study.** Photo courtesy Viktor Loki/www.shutterstock.com

⮟ **Further studies in this area may consider the impact of light pollution on damselfly larvae (Zygoptera) which live underwater.** Photo courtesy MP,cz/www.shutterstock.com

Other impacts

Shidemantle is considering looking at how light pollution impacts other organisms in wetland ecosystems that amphibians might interact with, such as damselfly larvae which are common predators of tadpoles. She received a grant from the National Science Foundation this year to further explore the effects of light pollution on amphibians.

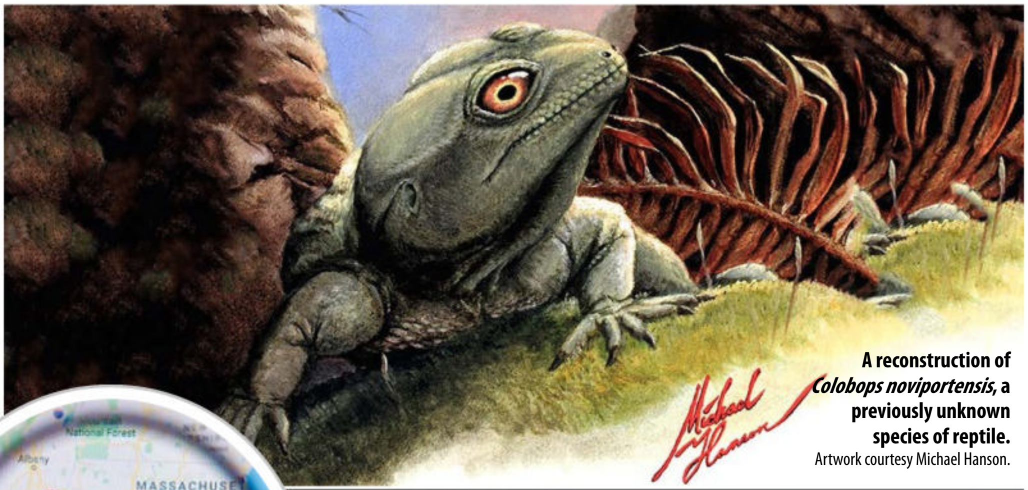
"It is critical to understand how humans impact wildlife so that we can make more responsible decisions about how we proceed with activities such as urbanisation and construction," says Shidemantle. "Also, it is likely that these effects of light pollution extend beyond just amphibians—the impacts on amphibians may have indirect effects on other organisms that they in turn interact with in their ecosystem."

Further information

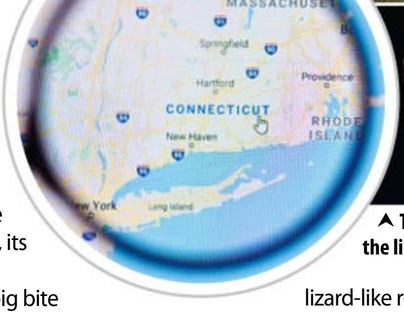
Dyllan May, Grascen Shidemantle, Quentin Melnick-Kelley, Kelly Crane, Jessica Hua. **The effect of intensified illuminance and artificial light at night on fitness and susceptibility to abiotic and biotic stressors.** *Environmental Pollution*, 2019; 251: 600 DOI: 10.1016/j.envpol.2019.05.016

Putting the bite on an ancient reptile from New England

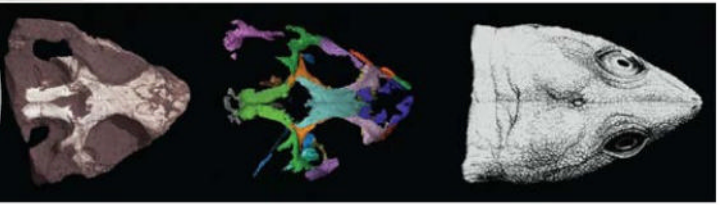
Scientists have identified a new species of reptile from prehistoric Connecticut with an incredible mouth! Named *Colobops noviportensis*, the creature lived 200 million years ago and had exceptionally large jaw muscles — setting it apart from other reptiles at the time, as far as is known. Even compared with the wide diversity of reptile species alive today, *Colobops noviportensis* had quite a bite.



A reconstruction of *Colobops noviportensis*, a previously unknown species of reptile. Artwork courtesy Michael Hanson.



^ Connecticut lies on the eastern side of the USA. Map courtesy Vladimir Sukhachev/www.shutterstock.com



^ This series of images shows the reconstruction process that researchers used for creating the likely appearance of *Colobops noviportensis*. Photo courtesy Adam C. Pritchard *et al*, CC BY-SA 4.0.

A formidable lifestyle

"Colobops would have been a diminutive but plucky little beast, part of a little-known menagerie of small animals that lived among the first dinosaurs," explains Bhart-Anjan Bhullar, assistant professor and assistant curator in geology and geophysics at Yale.

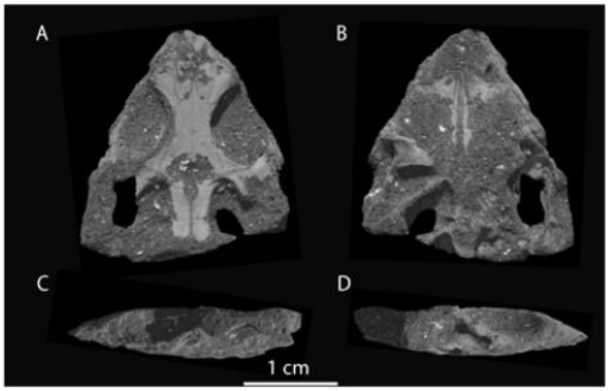
"Its tiny frame hid some big secrets," Bhullar says. "Despite its lizard-like appearance, it is in fact an early branch-off from the lineage leading to dinosaurs and birds. Also, its little jaws could bite harder than anything else its size. Perhaps that big bite allowed it to feed on tough, armoured prey impervious to weaker mouths."

Science advances

"This project was a great example of the process of science," observes Adam Pritchard, who is now based at the Smithsonian Institute. "The skull was originally discovered during 1965. Then in the 1990s, the skull was subject to further examination and was identified as belonging to a cousin of a modern lizard-like reptile called a tuatara. Our study progresses things forwards once more, using advanced CT scanning and 3D modeling to reveal all kinds of new features within the skull. The characteristics here are very distinctive, allowing us to establish it as a new species."

The specimen is a quarter-sized skull discovered in Meriden, Connecticut, during roadworks. It has been part of the collections of the Yale Peabody Museum of Natural History for decades. The specimen's new species name derives from 'Novus Portus', a Latinized version of New Haven — which is a reference to the New Haven Arkose geological formation.

v The original skull fossil of Colobops, seen from different angles. Photo courtesy Adam C. Pritchard *et al*, CC BY-SA 4.0.



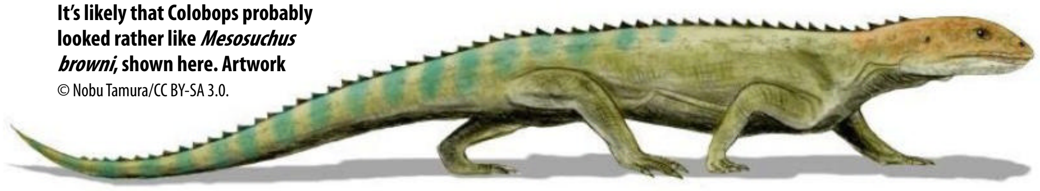
A fresh study

The Yale team took a new look at the specimen. The researchers did a 3D reconstruction of the skull and discovered that it showed specialisation in the jaw that was unprecedented in any other known small tetrapod, either juvenile or adult.

"Comparisons with modern reptiles showed that it had incredibly well-developed jaw muscles for its size, suggesting an exceptional bite, even compared with the diversity of modern reptiles," Pritchard said. "It's a great illustration of the critical importance of fossils, big or small, when it comes to understanding the diversity of organisms."

The researchers said the discovery means modern vertebrates originated in a world that was already populated by small and large-bodied physical extremes, reflecting how animals had physically adapted to their environment at that stage.

^ Initial studies suggested a relationship between Colobops and tuataras. Photo courtesy BeautifulBlossoms/www.shutterstock.com



It's likely that Colobops probably looked rather like *Mesosuchus browni*, shown here. Artwork © Nobu Tamura/CC BY-SA 3.0.

Further information

Adam C. Pritchard, Jacques A. Gauthier, Michael Hanson, Gabriel S. Bever & Bhart-Anjan S. Bhullar. **A tiny Triassic saurian from Connecticut and the early evolution of the diapsid feeding apparatus**. *Nature Communications*, 2018 DOI: 10.1038/s41467-018-03508-1

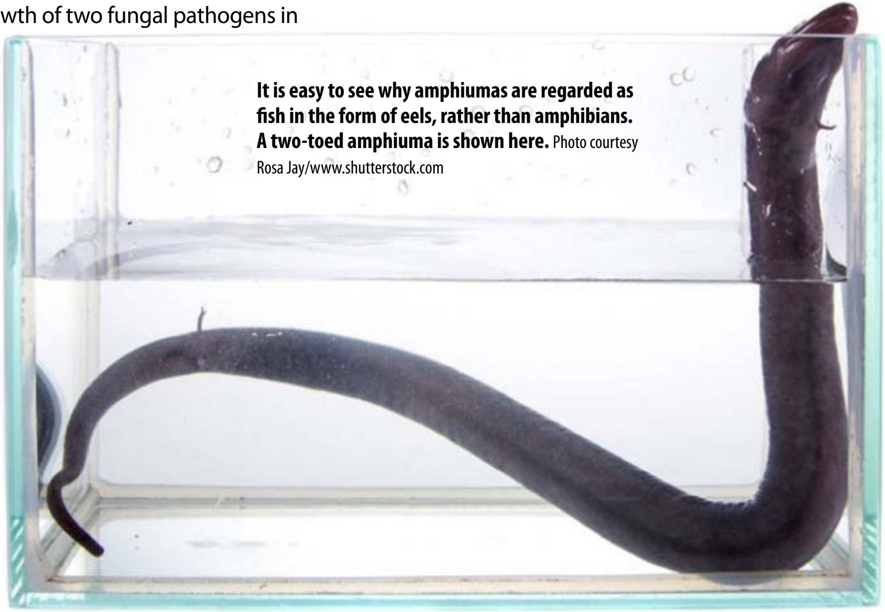
Resistance to deadly amphibian fungus

A three-toed amphiuma (*Amphiuma tridactylum*). Photo courtesy opencage/CC BY-SA 3.0.

Amphibian populations around the world are declining as a result of a skin disease caused by chytrid fungus. However, an amphibian which is commonly found in Louisiana, known as the three-toed amphiuma, has shown a resistance to the fungus, according to a new study led by researchers at Louisiana State University (LSU), Southeastern Louisiana University, Duquesne University and the University of Washington. This particular species is the second largest salamander in the world. It can grow to at least 91cm (3ft) in length and may weigh more than 3.2kg (7lb).

Amphibian skin is unique among vertebrates because it contains a large number of glands that produce and secrete substances that vary among species and have a diverse range of functions. The secretions of amphibian skin glands contain a rich array of bioactive compounds including antimicrobial compounds.

Such compounds are important for the amphibian's innate immune responses and some may seemingly protect certain species from the fungal disease affecting amphibians worldwide called chytridiomycosis. The scientists found compounds that inhibited the growth of two fungal pathogens in three-toed amphiumas.


It is easy to see why amphiumas are regarded as fish in the form of eels, rather than amphibians. A two-toed amphiuma is shown here. Photo courtesy Rosa Jay/www.shutterstock.com

LSU Department of Chemistry Professor John A. Pojman participated in the study by providing live and preserved three-toed amphiumas. "Although amphiumas, commonly called 'ditch eels,' are common throughout Baton Rouge, they are secretive and rarely observed. I've learned over the years of locations at which they can be captured year-round," Pojman adds.

Further information

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Flying reptiles over Britain

Photo courtesy Munimara/www.shutterstock.com

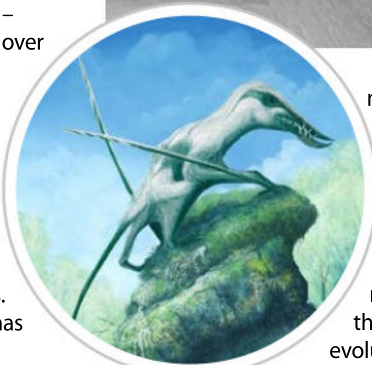
Spectacular flying reptiles armed with long teeth and claws which once dominated the skies have been rediscovered, thanks a palaeontology student’s PhD research. Dr Michael O’Sullivan, at the University of Portsmouth, has uncovered evidence of well-protected and substantial flying reptiles from historically important, but overlooked, British Jurassic fossils. He has also found a new species of pterosaur with a 2m (6.5ft) wingspan – as large as a modern mute swan, which would have made it a giant in its time.

A large population

Some 200 fossils of flying reptiles – pterosaurs – have been collected over the last two centuries from the Stonesfield Slate, also known as the Taynton Limestone Formation, which lies about 16km (10ml) northwest of Oxford. Yet their significance has been long neglected by palaeontologists, probably because they are mere fragments. Much of Dr O’Sullivan’s research has involved untangling the messy science associated with these neglected specimens. The quantity and quality of such fossils from the area might be why these fragments have until now been overlooked.

“The excellent marine reptiles and ammonites of the UK’s Jurassic heritage are widely known, but we celebrate our Jurassic flying reptiles far less,” says Dr O’Sullivan, who is based in the University’s School of Earth and Environmental Sciences.

Closer inspection has now revealed evidence of multiple pterosaur lineages in the UK’s Jurassic past however, including some unexpectedly large and formidably armed species. The new species has been named *Klobiodon rochei*. Dr O’Sullivan explains: “Klobiodon’s large fangs would have meshed together to form a toothy cage, from which little could escape once this pterosaur had grabbed its prey in its mouth.

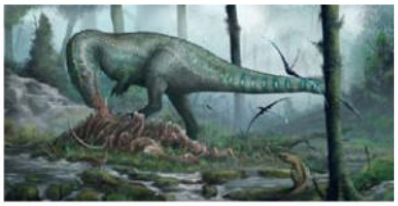

A reconstruction of how Klobiodon may have appeared. Artwork © Mark Whitten.

Unmasking the picture

“The Stonesfield pterosaurs are rarely pretty or spectacular, but they occupy a time in flying reptile evolution which is poorly represented globally. They have an important role to play in not only understanding the UK’s natural history, but in helping us understand the bigger global picture as well,” he adds.

The generic name of Klobiodon means ‘cage tooth’, in reference to its huge, fang-like teeth – measuring up to 26mm (1.1in) long at a time when few pterosaurs had any teeth – and the name of the species honours comic book artist Nick Roche, in recognition of the role that popular media has determining how extinct animals are portrayed.

Only the lower jaw of Klobiodon is known, but it has a unique dental configuration that allows it to be instantly distinguished from other pterosaurs. It was probably a gull or tern-like creature – a coastal flier that caught fish and squid using its enormous teeth and swallowed them whole.


Megalosaurus - which was the first dinosaur to be named - also came from this same location in the English county of Oxfordshire. Artwork © Mark Whitten.

An overlooked find

Dr O’Sullivan highlights the research difficulties inherent in working with these remains. “Klobiodon has been known to us for centuries, archived in a museum drawer and seen by dozens or hundreds of scientists, but it’s significance has been overlooked because it’s been confused with another species since the 1800s.”

Klobiodon and the other Stonesfield pterosaurs lived alongside one of the most famous and important dinosaurs in the world, in the guise of the predatory Megalosaurus, which was the first dinosaur ever named. But as global sea levels were higher, and the world was much warmer, their Jurassic Britain was comprised of a series of large tropical islands.

The new pterosaur would have been the same size as a mute swan in flight. Photo courtesy Karel Bock/www.shutterstock.com

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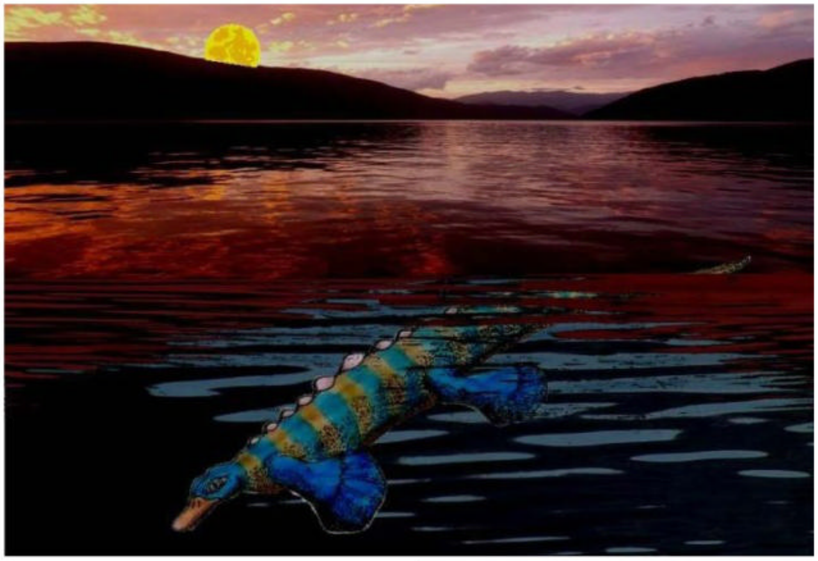
Reptile platypus from the Triassic

No animal alive today looks quite like a duck-billed platypus, but about 250 million years ago, in the Triassic time period, something very similar swam in the shallow seas of what is now China, finding prey by touch, using its cartilaginous bill. This newly discovered marine reptile is now known as *Eretmorhipis carrolldongi*.



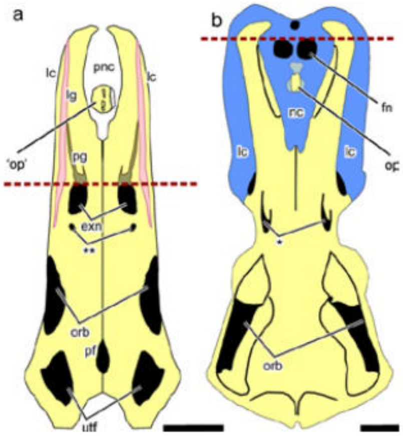
➤ Related to the dolphin-like ichthyosaurs, Eretmorhipis lived in a world devastated by the mass extinction event that took place at the end of the Permian era. Its small eyes and bill suggest that like the duckbilled platypus, it hunted by touch. Its colouration, however, is unknown.

Artwork courtesy Gianluca Danini.

Filling the gap

Apart from its platypus-like bill, Eretmorhipis was about 70cm (28in) overall, with a long rigid body, small head and tiny eyes, as well as four flippers that it used for swimming and steering itself. Protective bony plates ran down the animal's back.

Eretmorhipis was previously known only from partial fossils without a head. Professor Ryosuke Motani, a paleontologist at the University of California, Davis Department of Earth and Planetary Sciences explains: "This is a very strange animal. When I started thinking about its biology, I was really puzzled."



◀ Comparison of the skulls of the mammalian duck-billed platypus (*Ornithorhynchus anatinus*) (left), and the reptile *Eretmorhipis carrolldongi* on the right. Blue shading indicates cartilage. In the platypus, the bill is known to be sensitive to touch allowing the animal to hunt in low light conditions.

Illustration courtesy L. Cheng *et al*, *Scientific Reports*, CC BY-SA 4.0.

A similar lifestyle?

The two new fossils show the animal's skull had bones that would have supported a bill of cartilage. Like the modern platypus, there is a large hole in the bones in the middle of the bill. In the platypus, the bill is filled with receptors that allow it to hunt by touch in muddy streams.

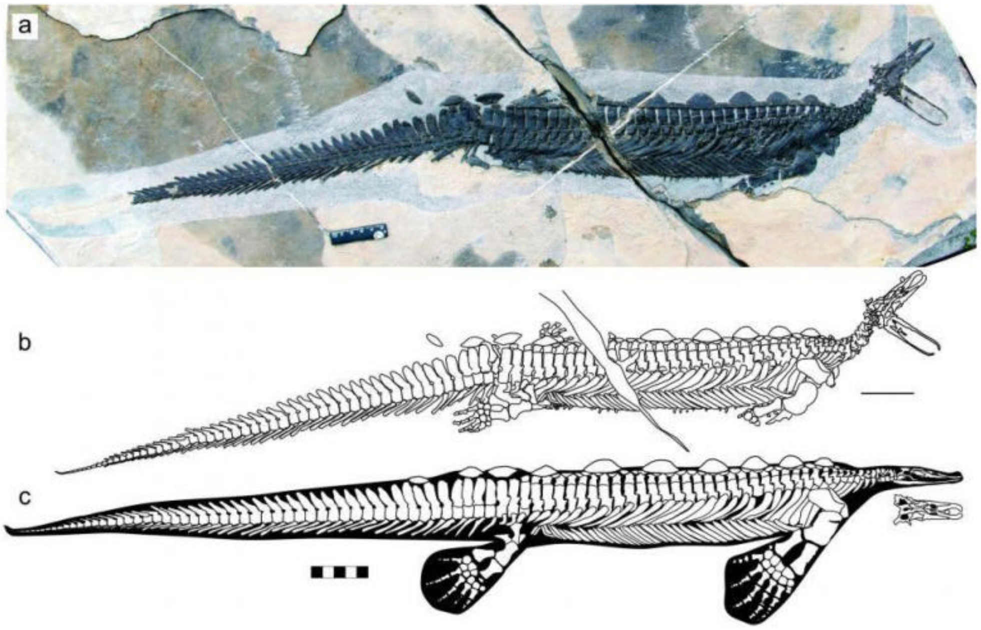
➤ A duck-billed platypus - a bizarre egg-laying mammal found in a limited area of Australia.

Photo courtesy worldswildlifewonders/www.shutterstock.com

During the early Triassic, the area where Eretmorhipis lived was covered by a shallow sea, about a metre (3.25ft) deep, over a carbonate platform extending for hundreds of miles.

Eretmorhipis fossils were found at what were deeper holes, or lagoons, in the platform. There are no fossils to show what Eretmorhipis ate, but it most likely fed on shrimp, worms and other small invertebrates, according to Motani.

Its long, bony body means that Eretmorhipis was probably a poor swimmer. "It wouldn't survive in the modern world, but it didn't have any rivals at the time," says Prof Motani. "Related to the dolphin-like ichthyosaurs, Eretmorhipis evolved in a world devastated by a mass extinction event. Its existence provides more evidence of the rapid evolution that was occurring as a result during the early Triassic."



A complete fossil and line drawing of *Eretmorhipis carrolldongi*. Courtesy L. Cheng et al, Scientific Reports, CC BY-SA 4.0.

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Fluorescent frog found

Pumpkin toadlets (*Brachycephalus ephippium*) are tiny, brightly-coloured and poisonous frogs that can be found in the Atlantic forest region of Brazil. During the spawning season, they can be encountered during the day, wandering around the forest floor, producing soft buzzing calls in search of a mate.

An international team of researchers led by NYU Abu Dhabi's Sandra Goutte began studying the acoustic communications of these miniature frogs. The scientists then discovered that the amphibians were actually deaf and could not hear their own mating calls, so they were forced to think again. They started to search for alternative visual signals that the frogs might use to communicate with each other instead. Unexpectedly, when they shone an ultraviolet (UV) lamp on the frogs, their backs and heads glowed intensely.

The mechanism

The researchers found that these fluorescent patterns are created by bony plates lying directly beneath an extremely thin area of skin. In fact, the toadlet's entire skeleton is highly fluorescent, but the fluorescence is only externally visible where the layer of skin tissue over the bones is no more than about seven micrometres thick.

The lack of dark skin pigment cells (which block the passage of light) and the thinness of the skin combine to allow the ultraviolet (UV) light to pass through and activate the fluorescence of the bony plates of the skull. The fluorescent light is then reflected back from the frog's bone, and can be seen as bluish-white markings by an observer equipped with a UV lamp.

A pumpkin toadlet on a fingertip.

Photo courtesy Sandra Goutte.

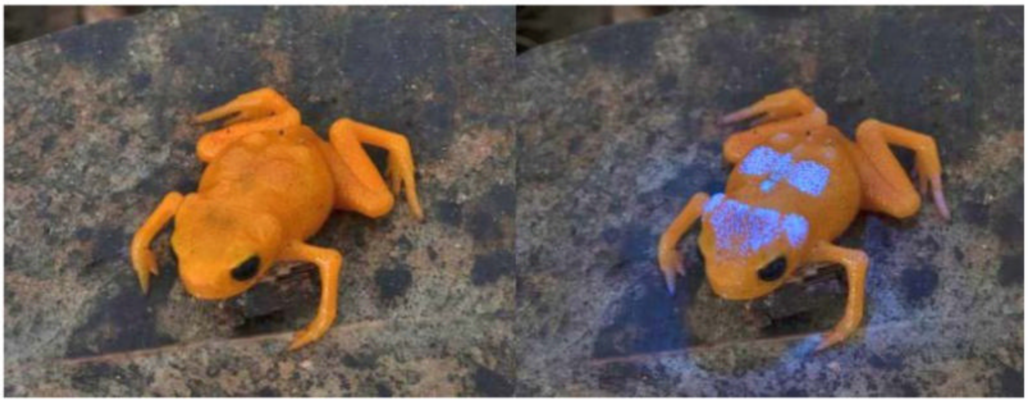
The second species of pumpkin toad, known as the pitanga toadlet (*Brachycephalus pitanga*), which is also deaf. Its name means 'red-coloured' in the native Tupi-Guarani languages in the area of south-eastern Brazil where it occurs. Photo courtesy Carlos Henrique Luz Nunes de Almeida/https://calphotos.berkeley.edu/CC_BY_3.0

Why do they glow?

"The fluorescent patterns are only visible to the human eye under a UV lamp. In nature, if they were visible to other animals, they could be used as intra-specific communication signals or as reinforcement of their aposematic colouration, serving as a warning potential predators of their toxicity," explains Goutte. "However, more research on the behaviour of these frogs and their predators is needed to pinpoint the potential function of this unique luminescence."

The researchers compared the skeletons of the two species of pumpkin toadlets to closely related, non-fluorescent species. The pumpkin toadlets' bones proved to be much more fluorescent. Pumpkin toadlets are diurnal, and in their natural habitat, the UV or near-UV components of daylight might be able to create fluorescence at a level detectable by certain species that can effectively see in the ultraviolet light spectrum - including probably their own.

Typical habitat where pumpkin toadlets occur, but development, resulting in forest clearance, is threatening their survival. Photo courtesy Vanessa Rung/www.shutterstock.com.



A pumpkin toadlet (*Brachycephalus ephippium*) under natural light (left) and ultraviolet light (right).

Photo courtesy NYU Abu Dhabi Postdoctoral Associate Sandra Goutte.

Further information

Sandra Goutte, Matthew J. Mason, Marta M. Antoniazzi, Carlos Jared, Didier Merle, Lilian Cazes, Luís Felipe Toledo, Hanane el-Hafci, Stéphane Pallu, Hugues Portier, Stefan Schramm, Pierre Gueriau, Mathieu Thoury. **Intense bone fluorescence reveals hidden patterns in pumpkin toadlets.** *Scientific Reports*, 2019; 9 (1) DOI: 10.1038/s41598-019-41959-8

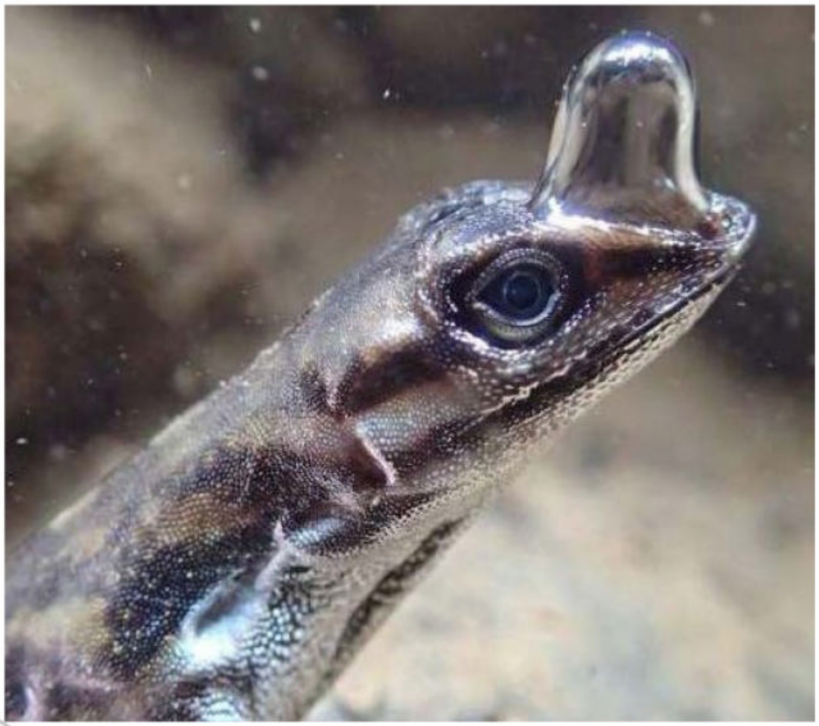
Scuba-diving lizard found

A Costa-Rican lizard species may have evolved scuba-diving skills allowing it to stay underwater for up to 16 minutes, according to the findings of a study carried out at Binghamton University, State University of New York. Lindsey Swierk, assistant research professor of biological sciences, has revealed that the water anole (*Anolis aquaticus*) is able to breathe under water for long periods of time to escape from predators.

It appears that the species may have formed an underwater respiration system consisting of a recycled air bubble that clings to its head.

"Diving under water and remaining there for a long time is an anti-predator strategy used by water anoles," says Swierk. "These lizards aren't particularly speedy, and taking to the water is a very effective option. Take it from a biologist who sometimes struggles to capture her study organism because they're so good at diving!

"It's easy to 'disappear' out of sight of a predator once you hide in the water for a few minutes. I think that any underwater breathing adaptations in water anoles would have arisen to extend the amount of time they can stay in their underwater refuge."


➤ **The water anole underwater.**
Photo courtesy Lindsey Swierk.

➤ **Aside from their diving and swimming abilities, these lizards are also well-protected by camouflage.**
Photo courtesy Etienne Boncourt (Goodshoirt)/CC-BY-3.0/Wikimedia Commons.

A chance discovery

The unique behaviour was documented for the first time by Swierk in a video that shows the anole breathing out and re-inhaling an air pocket under water. Swierk first noticed this species when she was walking along the mountain streams in Costa Rica and observed the lizards dive under water and stay submerged for a long period of time. Further analysis of the lizards' stomachs uncovered that they eat some insects that are mainly found under water, hinting that the species may also dive under water for reasons other than just avoiding predators.

"Finding evidence suggesting that water anoles 'breathe' underwater was serendipitous, and not part of my original research plan," admits Swierk. "I was impressed and pretty confused about the length of the dive, which gave me an itch to take a closer look with an underwater camera. That's when I saw that the anoles appeared to be rebreathing a bubble of air that covered their heads."

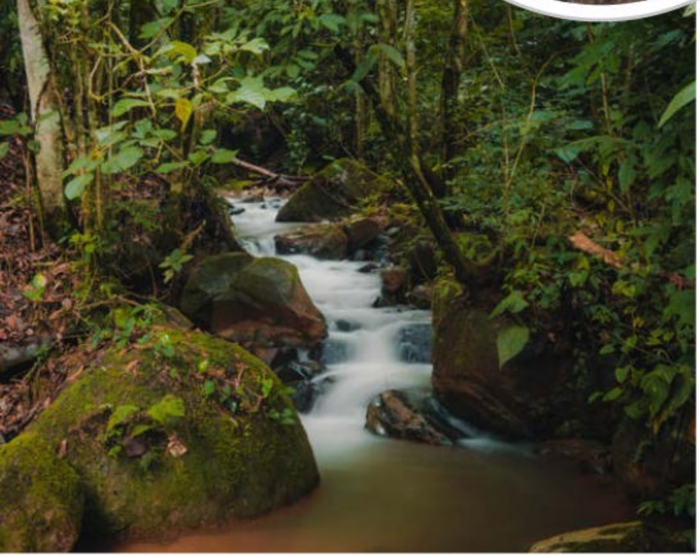
More questions raised

Swierk believes the lizard might also be extracting oxygen from these bubbles. "I think it's possible that some additional air pockets are being trapped around the anole's head and throat, and that the inhalation and exhalation of the air bubble allow for some trading of fresh air among these air pockets, allowing the anole to swap air in its current air bubble with 'new' air," she explains.

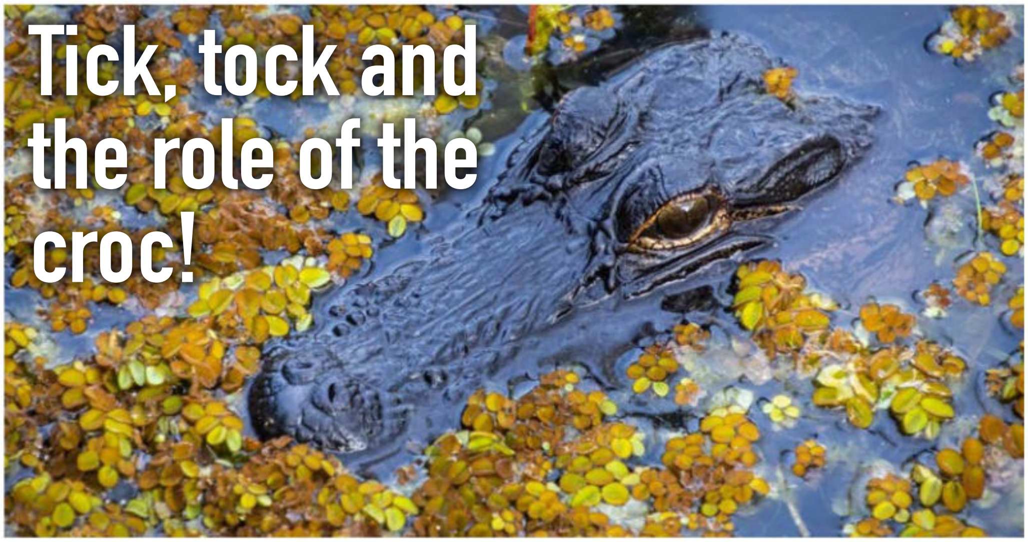
"It's additionally possible that the air bubble plays a role in allowing an anole to get rid of carbon dioxide. I suspect that there might be morphological adaptations, namely the shape of the top of the anole's head, which allows a large bubble of air to cling to it easily."

Swierk's lab plans to investigate further, with several areas of further research into "bubble-breathing" being targeted, They hope to tackle questions related to the anti-predator function of air bubble breathing in the wild; how anole head shape influences bubble formation and the physiology underlying this potential adaptation.

"If future investigation reveals that this rebreathing behaviour is adaptive, then I would imagine that it is a trait that evolved over time to allow water anoles, and perhaps similar anole species, to thrive in their aquatic habitats," suggests Swierk, who is publishing her findings in the *Herpetological Review*.


➤ **The typical type of habitat in Costa Rica where these lizards occur.**
Photo courtesy Stiven Beitia R/www.shutterstock.com

Tick, tock and the role of the croc!



Even today, there are variations in relative hardiness between different groups of crocodilians. Alligators, like this American individual (*Alligator mississippiensis*) are better-able to survive in colder areas than crocodiles, and have developed specific survival strategies for this purpose. Photo courtesy Phil Lowe/www.shutterstock.com

Underneath their tough exteriors, some crocodilians have a vulnerable side that scientists could use to shine light on our ancient climate, according to the latest research. The idea of a clock ticking inside a crocodile was of course featured by author JM Barrie in his famous story of *Peter Pan*, but instead of telling the current time, ancient crocodilians could serve as climate "clocks" – giving a vital insight into the climate of the past, in a similar way to the use of tree rings and ice cores.

This is now possible because scientists have discovered that some species of crocodilian in the past were sensitive to changes in climate while others were more tolerant. Mapping the distribution of these different species using fossil remains could reveal more precise details about what the global climate was like in different locations millions of years ago.

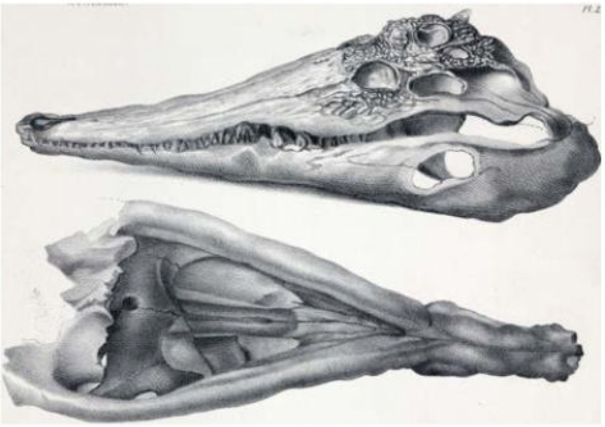
"Our analysis suggests that crocodilians are even less of a homogenous group than previously thought and that some alligator-like reptiles were particularly good at tolerating the dramatic changes in climate that marked the end of the Eocene epoch about 34 million years ago, and the beginning of the Oligocene," says Dr Stéphane Jouve from France's University of Sorbonne.

The transition between these epochs was marked by a climatic crisis, during which temperatures plummeted, sea levels fell drastically and many plants and animals went extinct as a result. Previous studies have suggested that crocodilians were one of the species to decline in diversity, but the new fossil analysis suggests that while a number of species did die out, others migrated to warmer waters and some still managed to survive.

Cold weather impacts

The coastal environment was transformed by the decline in sea level and some marine longirostrine crocodilians escaped the cold of Europe by migrating south to North Africa. The palaeontologists suggest that Morocco could have been the platform for other marine species, in the gavialoid family, to migrate to South America. Meanwhile, the marine tomistomines, a family of crocodilians whose distribution once included England, progressively disappeared from north to south, as the freeze continued.

Freshwater species were not affected by the shift in sea level but some could not survive the rapid decline in temperatures occurring in the late Eocene and became extinct. Meanwhile, the alligator-like freshwater *Diplocynodon* continued to survive even the lowest temperatures of the early Oligocene epoch. Compared with the gavialoids and tomistomines, it survived a large range of latitudes, extending from Spain to cooler England.



A representation of the skull of a marine tomistomine called *Kentisuchus*, which was excavated on the Isle of Sheppey in the county of Kent in southern England. Photo courtesy J. E. Girardot/ PD.

Diplocynodon was an alligator-like crocodilian that used to live in Europe — including areas of what is now England. This specimen is on display at the Musee d'Histoire Naturelle in Paris.
Photo courtesy Ghedoghedo/Wikipedia/CC-BY-3.0.

A fossil of the Eocene crocodile *Hassiacosuchus haupti*, unearthed from Messel. Tracking the distribution of extinct crocodiles is now given valuable insight into how the climate may have changed. Photo courtesy Patrick Bürgler, Pflasterzahn-Krokodil, CC-BY-2.0

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An island haven for amphibians

New Guinea is one of the only places in the world where frogs are safe from the species-destroying chytrid fungus. An international team of scientists has published a new paper that shows how to keep it that way, but they need help to carry out their plan.

Chytrid fungus has wiped out more than 90 frog species around the world, and it's driving hundreds more towards extinction. New Guinea – the world's largest tropical island, and home to 6% of all known frog species – is one of the last remaining refuges free from this deadly infection.

A team of scientists led by researchers from Macquarie University and the University of New England in Australia believe they know how to keep the island's frogs safe, but they need support to establish a long-term programme of monitoring and conservation.

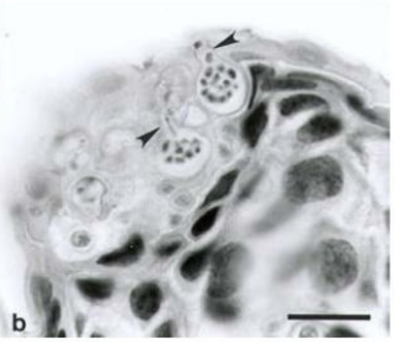
The scale of the problem

The group of 30 experts from Australia, the USA, China, Indonesia and Papua New Guinea calls for urgent action. "You don't often spot a conservation disaster before it happens and get the chance to stop it," says Deborah Bower of the University of New England in Armidale, Australia. "We know what needs to be done."

The infectious chytrid fungus has been described as the most destructive pathogen known to science. It has destroyed more than 90 species of frog entirely and caused declines in almost 500 more, on every continent. It is one of the key reasons why 40% of the world's frog species now face the threat of extinction.

➤ The Wokan cannibal frog (*Lechriodus melanopyga*) is an endemic New Guinea amphibian, found nowhere else on the planet. It is common on its native island. Photo courtesy Rémi Bigonneau/Wikipedia/CC-BY-4.0.

➤ The angiana tree frog (*Litoria angiana*) is another endemic species of frog that would be at threat from chytrid fungus if the disease reached New Guinea. Photo courtesy Marc Dragiewicz/Wikipedia/CC-BY-SA 2.0.



➤ Key characteristic signs of the fungus in a skin of a frog. Photo courtesy Peter Daszak, Lee Berger, Andrew A. Cunningham, Alex D. Hyatt, D. Earl Green, and Rick Speare/Wikipedia/PD.

The risk to native species

New Guinea's tropical climate and hundreds of native frog species make it an ideal environment for chytrid. But field tests have so far found no traces of the killer fungus. "A lot of New Guinea's frogs are closely related to Australian species that have been devastated by chytrid, so we expect they would be just as vulnerable," says Simon Clulow at Macquarie University in Sydney, Australia, who leads the research team.

"Other New Guinea frog species are unusual because they hatch from eggs as fully formed frogs, rather than going through a tadpole stage, and we don't know how chytrid might affect them."

The team estimates that around 100 species of frog would be in danger if chytrid reaches New Guinea, and their decline could have huge impacts across the ecosystem as they are predators of insects and other small creatures but also prey for larger animals.

The research team includes international experts in frog conservation – including Lee Berger, the Australian who first discovered the chytrid fungus and showed it was responsible for declines and extinctions amongst frog species – alongside local researchers with deep knowledge of the environment of New Guinea.

A plan in place

They have been studying frogs in New Guinea since 2015, and have already started working with zoos, universities and the Papua New Guinea government to build a programme to keep captive frogs and store their sperm and eggs to preserve genetic diversity.

The team has developed a five-step programme of preparation, prevention, detection, response and recovery to keep the deadly fungus off New Guinea and to minimise the impact if it does arrive. As well as preserving New Guinea's frogs, the programme will build local capacity in science, disease surveillance and diagnosis that will have applications for animal and public health.

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Elephant aid

Frogs need elephants. That's the conclusion of a new study led by the Wildlife Conservation Society (WCS), which looked at the role of water-filled elephant tracks in providing predator-free breeding grounds and pathways connecting frog populations.

The researchers found that rain-filled tracks of Asian elephants (*Elephas maximus*) in Myanmar's Htamanthi Wildlife Sanctuary were filled with frog egg masses and tadpoles. The tracks can persist for a year or more and provide temporary habitat during the dry season where alternate sites are unavailable. Trackways could also function as "stepping stones" that connect frog populations.

Elephants are widely recognised as "ecosystem engineers," being able to extensively modify vegetation through browsing, trampling, and seed dispersal. They also convert large amounts of plant biomass into dung that is an important nutrient addition for both terrestrial and aquatic systems.

At smaller scales, the diversity of local plant species is enhanced when elephants open gaps in the forest canopy. Meanwhile, browsing damage to trees creates refuges for small vertebrates (such as lizards and small mammals), while their dung piles provide food for a diversity of beetles.

Asian elephants are drawn to wet areas, and their footprints can create suitable spawning pools for frogs in damp ground.
Photo courtesy David Alderton.

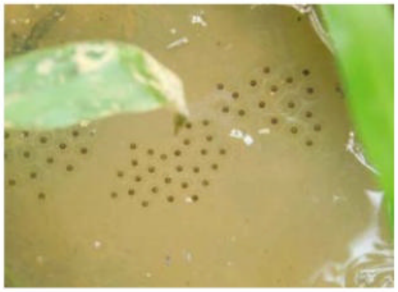
▲ Elephant footprints can provide vital areas for spawning purposes.
Photo courtesy chai na phon phochadee/www.shutterstock.com

▼ The resulting holes fill with water in the wet season, transforming into small ponds.
Photo courtesy Steven Platt.

Interactivity rules!

However, most research on ecosystem engineering by elephants has focused on savanna elephants (*Loxodonta africana*) and to a lesser extent, forest elephants (*Loxodonta cyclotis*) in Africa; the role of Asian elephants as ecosystem engineers is much less well-known. Unfortunately, they are considered Endangered by IUCN as a result of habitat loss, poaching and retribution for crop raiding and human/elephant conflict.

Steven Platt, Associate Conservation Herpetologist with WCS's Myanmar Program notes: "Elephant tracks are virtual condominiums for frogs! This study underscores the critical role that wildlife plays in ecosystems in sometimes unexpected ways. When you lose one species, you may be unknowingly adversely affecting others, which is why protecting intact ecosystems with full assemblages of wildlife is so important."


▲ Developing frog spawn in an elephant track.
Photo courtesy Steven Platt.

▲ The team examining elephant tracks.
Photo courtesy Steven Platt.

Further information

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Hidden threat to bumblebees

An American bumblebee. Like other bumblebees, this species is becoming an increasingly rare sight for a variety of reasons. Photo steve52/www.shutterstock.com

Many species of wild bumblebees are in decline, and new research shows that diseases spread by domestic honeybees may be a major culprit.

Several of the viruses associated with bumblebees are moving from managed bees in apiaries to nearby populations of wild bumblebees.

"This spillover is likely occurring through flowers that both kinds of bees share," says Samantha Alger, a scientist at the University of Vermont who led the new research. "Many wild pollinators are in trouble and this finding could help us protect bumblebees," she says. "This has implications for how we manage domestic bees and where we locate them."

Virus hunters

Around the globe, the importance of wild pollinators has been gaining attention as diseases and declines in managed honeybees threaten key crops. Less well understood is that many of the threats to honeybees (*Apis mellifera*) – including land degradation, certain pesticides, and diseases – also threaten native bees, such as the rusty patched bumblebee, recently listed under the *Endangered Species Act*; it has declined by nearly 90% but was once an excellent pollinator of cranberries, plums, apples and other agricultural plants.

A rusty-patched bumblebee. This is one of the North American species now regarded as endangered.
Photo courtesy Emily Dickinson, US Geological Survey/PD.

The research team, which also included a member from the University of Florida, explored 19 sites across Vermont. They discovered that two well-know RNA viruses found in honeybees – deformed wing virus and black queen cell virus – were higher in bumblebees collected less than 300m (985ft) from commercial beehives.

The scientists also discovered that active infections of the deformed wing virus were higher near these commercial apiaries. But no deformed wing virus was found in the bumblebees they collected where foraging honeybees and apiaries were absent.

Flowers give a clue

Most significantly, however, the team detected viruses on 19% of the flowers they sampled from sites near apiaries. "I thought this was going to be like looking for a needle in a haystack. What are the chances that you're going to pick a flower and find a bee virus on it?" admits Alger. "Finding this many was surprising." In contrast, the scientists didn't detect any bee viruses on flowers sampled more than 1km (0.6ml) from commercial beehives.

They and other bee experts have for some years suspected that RNA viruses

Both honeybees and bumblebees are attracted to similar flowers, such as white clover, and these have now been shown to facilitate the spread of viral infections between these two groups. Photo courtesy Malachi Jacobs/www.shutterstock.com

Photo courtesy Joe McDonald/www.shutterstock.com

might move from honeybees to bumblebees through shared flowers. But, with the exception of one small study in a single apiary, the degree to which these viruses can be transmitted in this way, with flowers as the bridge, has not been examined until now.

Taken together, these results strongly suggest that "viruses in managed honeybees are spilling over to wild bumblebee populations and that flowers are an important route," says Alison Brody, a professor in UVM's Department of Biology. "Careful monitoring and treatment of diseased honeybee colonies could protect wild bees from these viruses as well as other pathogens or parasites."

Just like chicken?

Alger, who is both an expert beekeeper and researcher in UVM's Department of Plant & Soil Science and Gund Institute for Environment, is deeply concerned about the long-distance transport of large numbers of honeybees for commercial pollination. "Big operators put hives on flatbed trucks and move them to California to pollinate almonds and then onto Texas for another crop," she explains. "They therefore carry their diseases wherever they go.

There is another danger as well. Between bouts of work on monoculture farm fields, commercial bees are often taken to more pristine natural habitats. "Here they rest and recover, where there is diverse, better forage," says Alger.

So what is the answer? "This research suggests that we might want to keep apiaries outside of areas where there are vulnerable pollinator species, like the rusty patched bumblebees," Alger says. "Especially because we have so much more to learn about what these viruses are actually doing to bumblebees."

Honeybees are an important part of modern agriculture. "However, they're non-native. They're livestock animals," explains Alger. "A huge misconception in the public mind is that honeybees serve as the iconic image for pollinator conservation. That's ridiculous. It's like making chickens the iconic image of bird conservation!"

▲ Beehives are often transported over long distances, being taken to where they are needed, potentially moving infections over large areas too.

Photo courtesy Brandy Kunzman Photog/www.shutterstock.com

▼ The sheer numbers of bees in a colony, and their social structure, means that infections can spread rapidly once a group becomes infected.

Photo courtesy Maddas/www.shutterstock.com

Further information

Samantha A. Alger, P. Alexander Burnham, Humberto F. Boncristiani, Alison K. Brody. **RNA virus spillover from managed honeybees (*Apis mellifera*) to wild bumblebees (*Bombus* spp.).** *PLOS ONE*, 2019; 14 (6): e0217822 DOI: 10.1371/journal.pone.0217822

Effective conservation measures assist giant South American river turtles

Analysing records in countries within the Amazon and Orinoco river basins – which include Brazil, Venezuela, Colombia, Bolivia, Peru and Ecuador – has highlighted the fact that there have been 85 past and present initiatives or projects working to conserve the South American river turtle, known locally as the charapa (*Podocnemis expansa*), which is a striking yet critically endangered species in some areas. These projects are protecting more than 147,000 female turtles across the basin, which is an unprecedented figure.

There were 29 Latin American researchers and scientists who contributed to the study, with this collaboration stemming back to a 2014 workshop which was held in Balbina, Brazil. Here, park rangers, indigenous people, and conservationists from the six countries met to provide information on their work to protect the charapa. The efforts discussed there and subsequent follow-up reveal the serious commitment of both public and private bodies to conserve this iconic species.

An adult charapa or giant South American river turtle.
Photo courtesy Mauricio.

⮝ The aim in protecting the females in particular is to increase the number of eggs laid, boosting the chances of a greater number of young hatchlings surviving to breed in due course.
Photo courtesy Tarcisio Schnaider/www.shutterstock.com

Background

The charapa is considered the largest river turtle in South America. Its carapace (the top of its shell) can measure up to about 1.1m (3.5ft) in overall length, and the biggest individuals can weigh as much as 90kg (200lb). It inhabits the tributaries of the Amazon and Orinoco river basins, and is an important cultural symbol for many communities in the region.

The species also has great ecological importance for ecosystems, as it helps to transport fruits and seeds along the rivers, and also serves as prey for birds, catfish, foxes, jaguars and caimans amongst others. In the twentieth century, hundreds of thousands of turtles spawned on beaches throughout the continent.

Despite their local importance and past abundance, turtle populations are still threatened by the hunting and collection of adults and juveniles, looting of nests, the illegal trafficking of hatchlings, and the use of inappropriate fishing gear which can harm or kill individuals. In addition, broader degradation of their habitat is contributing to their decline.

Local involvement critical

Germán Forero, Scientific Director with WCS Colombia, has called for the creation of a protection network for the charapa. This would be in the form of a regional monitoring programme that would link technical information and lessons learned among all the projects in the six countries. He noted the importance of communities in this future network.

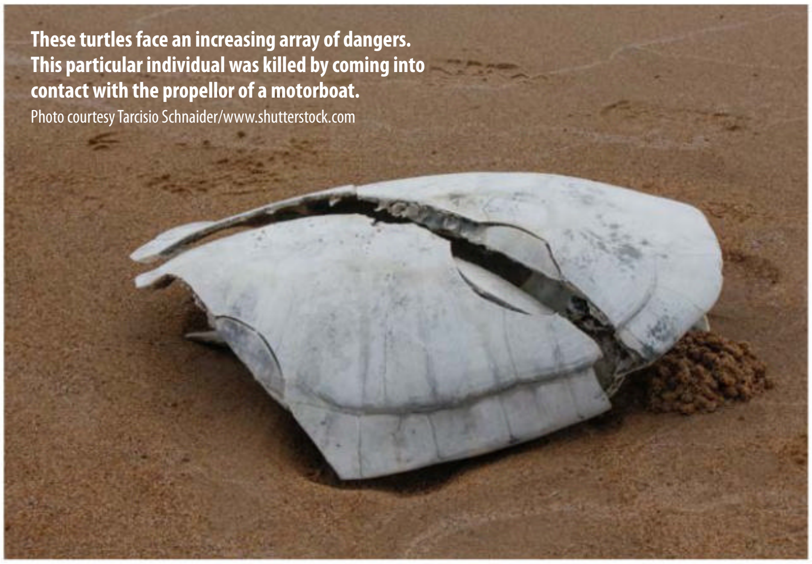
"The participation of local communities that live alongside the charapa is essential to protecting these turtles," explains Forero. "They live side by side with the them and are interested in controlling or preventing the commercialisation of eggs or meat to ensure the ongoing sustainability of the species as a food source and important part of their culture."

Camila Ferrara, a researcher with WCS Brazil, points out that the formation of this network would be extraordinary, because it would allow stakeholders to design and assess methodologies for management and conservation of the species, from egg-laying and protection of nesting beaches to population monitoring.

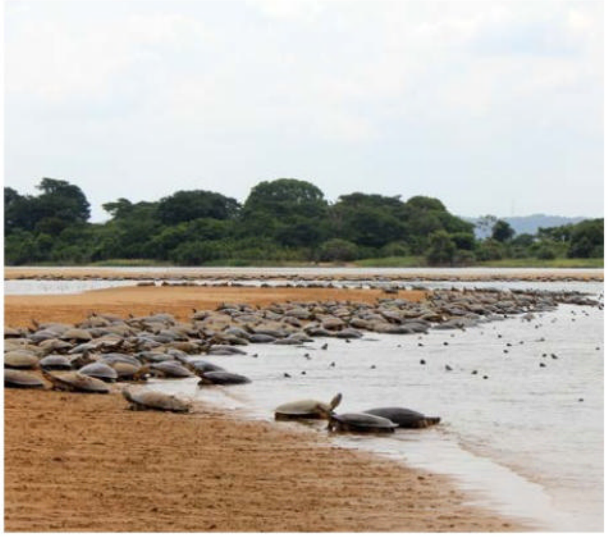
The case in Brazil

In Brazil, the charapa is not considered

➤ Charapa (*Podocnemis expansa*) turtles sunning.
Photo courtesy Mauricio.



These turtles face an increasing array of dangers. This particular individual was killed by coming into contact with the propellor of a motorboat.
Photo courtesy Tarcisio Schnaider/www.shutterstock.com



▲ The females nest during the dry season, when the sandbars in the rivers are exposed. The timing of the breeding periods is vital, as the young must hatch before the water level rises again, as this would drown them in their eggs.
Photo courtesy Tarcisio Schnaider/www.shutterstock.com

▲ A young hatchling emerges from a nest on a sandbar. Photo courtesy Tarcisio Schnaider/www.shutterstock.com

critically endangered, but ranks as a near-threatened species. Ferrara explains that although Brazil is home to important populations of the species, the turtle is still the second most consumed vertebrate group in the Amazon, surpassing even some fish. Therefore, she believes that the network should focus their efforts on strengthening environmental education in Brazil to ensure the sustainability of the reptile's consumption.

Ferrara explains: "We are seeing positive results as work progresses, as communities are expressing greater interest in working with turtles. We have seen a decrease in the consumption of eggs, an important achievement that we must replicate throughout the continent."

The paper highlights the importance of the monitoring conducted by the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), which provides the only way to assess the trends of populations over time and thus provides valuable information for decision-making on the species.

In Colombia, initiatives are working to protect at least two large populations - one in the Caquetá River in the Amazon basin and another in the Meta River within the Orinoco basin. In both areas, local communities are committed to protecting the nesting females at beaches, and these programmes are expected to receive continued support over time.

Not too late…

Going forward, the proposed network plans to develop a platform that can serve as an observatory of the species, tracking population trends across the basin over time to prioritise intervention sites and ensure the long term conservation of the species.

Rick Hudson, President of the Turtle Survival Alliance (TSA), believes that interest in protecting the charapa in South America comes at an opportune moment, as there are still robust populations of river turtles to protect; this is not the case in Asia, where many of turtle species have already gone extinct.

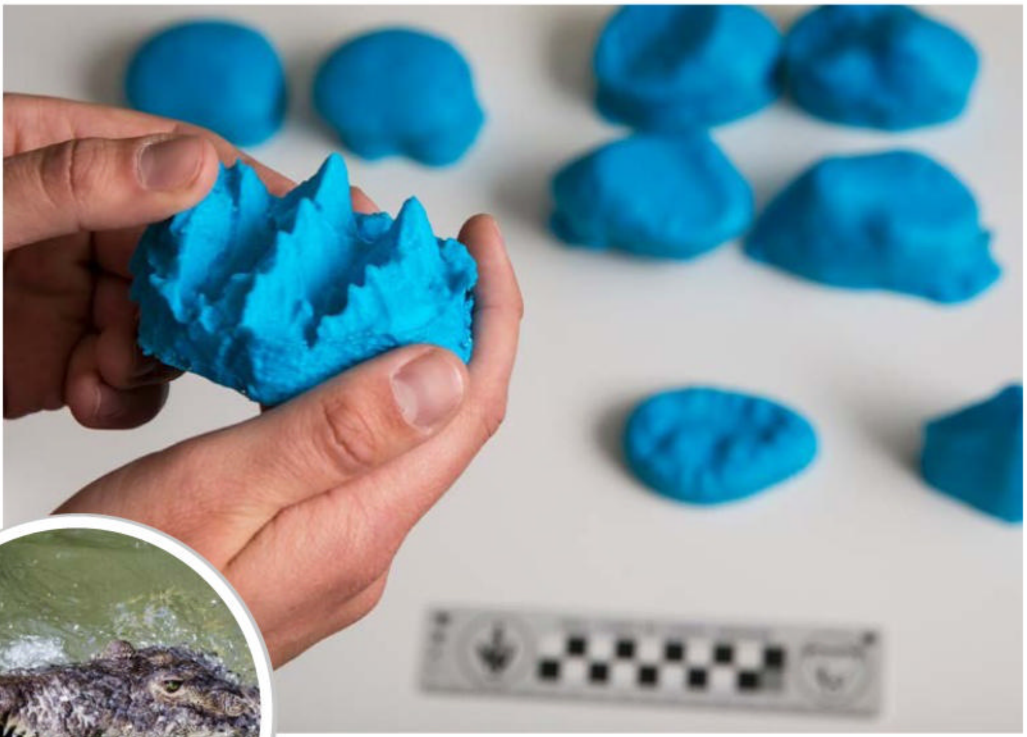
Hudson adds: "The lesson is clear: protect the habitat and large nesting aggregations of river turtles now and avoid crisis management in the future. This research makes a strong case for improving levels of protection while there is still time."

◀ The flattened profile of these turtles indicates their aquatic nature, enabling them to swim with relative ease.
Photo courtesy Tarcisio Schnaider/www.shutterstock.com

Further information

German Forero-Medina, Camila R. Ferrara, Richard C. Vogt, Camila K. Fagundes, Rafael Antônio M. Balestra, Paulo C. M. Andrade, Roberto Lacava, Rafael Bernhard, Alison J. Lipman, Ana Julia Lenz, Arnaldo Ferrer, Arsenio Calle, Andres F. Aponte, Bayron R. Calle-Rendón, Cássia Santos Camilo, Elis Perrone, Esteban Miraña, Fabio A. G. Cunha, Eva Loja, Jennifer Del Rio, Jorge Luiz Vera Fernandez, Omar E. Hermández, Rafael Del Aguila, Rafael Pino, Ruben Cueva, Sindy Martinez, Virgínia Campos Diniz Bernardes, Lila Sainz, Brian D. Horne. **On the future of the giant South American river turtle *Podocnemis expansa*.** *Oryx,* 2019; 1 DOI: 10.1017/S0030605318001370

Vegetarian crocs

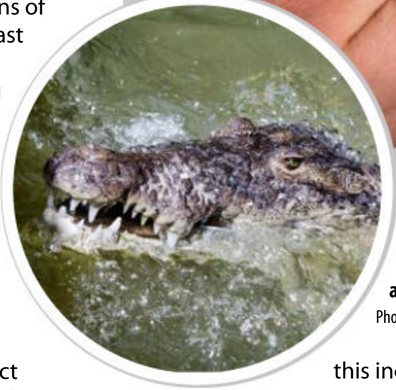


⮝ **3D tooth prints of the extinct crocodyliform *Chimaerasuchus* and other fossil crocodyliforms. These extinct animals had an impressive diversity of tooth shapes, unlike their living relatives, and some are extremely complex, such as *Chimaerasuchus*, suggesting an herbivorous diet.** Photo courtesy Keegan Melstrom/NHMU.

Based on careful study of fossilised teeth, scientists Keegan Melstom and Randall Irmis at the Natural History Museum of Utah (NHMU) at the University of Utah have found that multiple ancient groups of crocodyliforms – the group including living and extinct relatives of crocodiles and alligators – were not the carnivores we know today. In fact, the evidence suggests that a veggie diet arose in the distant cousins of modern crocodylians on at least three distinct occasions.

"The most interesting thing we discovered was how frequently it seems extinct crocodyliforms ate plants," reveals Keegan Melstrom, a doctoral student at the University of Utah. "Our study indicates that complexly-shaped teeth, which we infer to indicate herbivory, appear in the extinct relatives of crocodiles at least three times and maybe as many as six."

All living crocodylians possess a similar general body shape and ecology to match their lifestyle as semiaquatic generalist carnivores, and this includes having relatively simple, conical teeth. It was clear from the start of this study that extinct species showed a different pattern, including a number with many specialisations not seen today. One such trait is a feature known as heterodonty: this reflects regionalised differences in tooth size or shape.

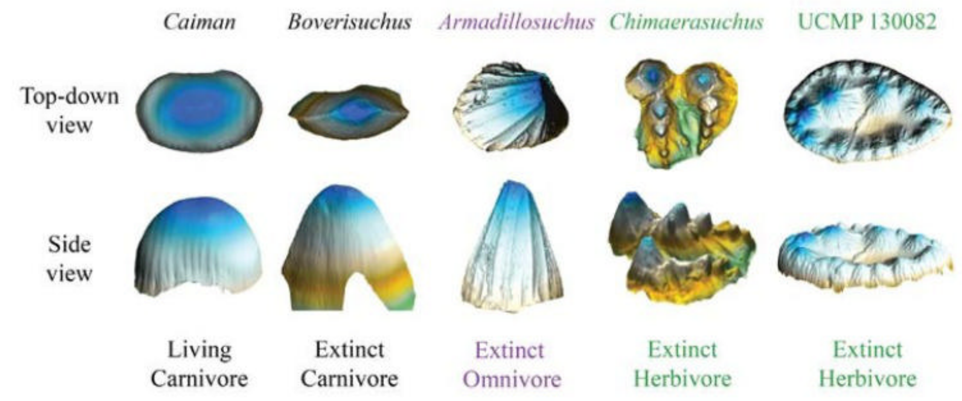


⮝ **Comparisons of the teeth played a key part in this study.** Photo courtesy HazaelGonzalez/ ww.shutterstock.com

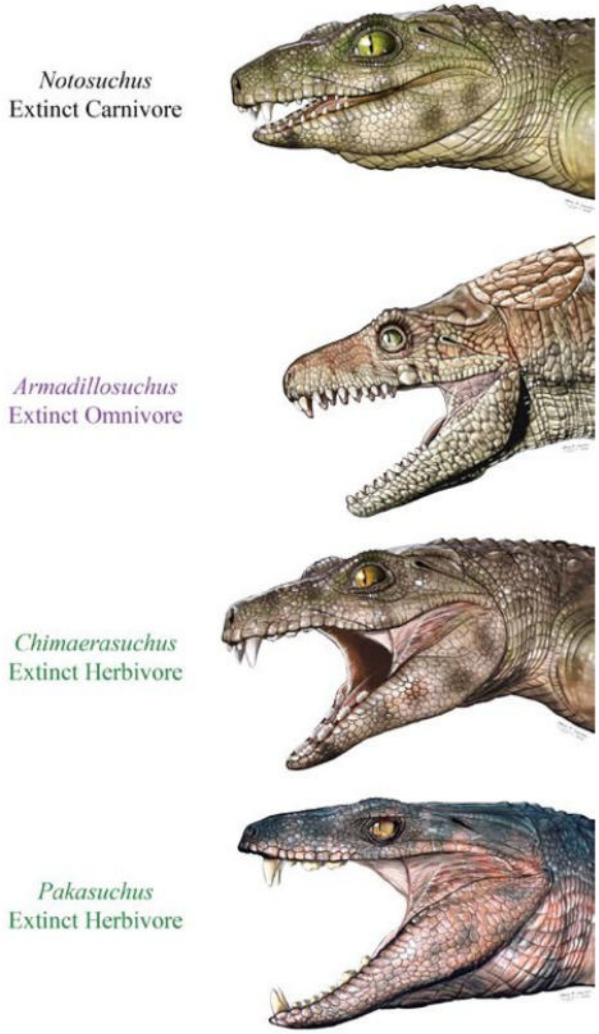
Diversity detection

"Carnivores possess simple teeth whereas herbivores have much more complex teeth," Melstrom explains.

⮝ **Today's crocodiles all have relatively simple conical teeth, as shown by this saltwater crocodile (*Crocodylus porosus*).** Photo courtesy dpi sutra stock/www.shutterstock.com



⮝ False colour 3D images showing the range in shape of crocodyliform teeth. Carnivores (left), such as the living caiman, have simple teeth, whereas herbivores (right) have much more complex teeth. Photo courtesy Keegan Melstrom/NHMU.



⮝ Life reconstructions of extinct crocodyliforms. Differences in tooth shape are related to differences in diets. Photo courtesy Keegan Melstrom/NHMU.

“Omnivores, being organisms that eat both plant and animal material, fall somewhere in between. Part of my earlier research showed that this pattern holds in living reptiles that have teeth, such as crocodylians and lizards.

These results told us that the basic pattern between diet and dentition is found in both mammals and reptiles, despite very different tooth shapes, and is also applicable to extinct reptiles.”

To infer what those extinct crocodyliforms most likely ate, Melstrom and chief curator Randall Irmis compared the tooth complexity of extinct crocodyliforms with those of living animals, adopting a method originally developed for use in living mammals. Overall, they measured 146 teeth from 16 different species of extinct crocodyliforms.

Using a combination of quantitative dental measurements and other morphological features, the researchers reconstructed the diets of those extinct crocodyliforms. The results show that those animals had a wider range of dental complexities and presumed dietary ecologies than had been appreciated previously.

The historical record

Plant-eating crocodyliforms appeared early in the evolutionary history of the group, according to the researchers, shortly after the close of the Triassic Period, about 200 million years ago, perhaps benefiting from the mass extinction that occurred then. They persisted until the end the Cretaceous, which took place 66 million years ago, disappearing in the mass extinction that also killed off all dinosaurs except birds. The study suggests that herbivory arose independently on at least three occasions, and possibly as many as six, in the case of Mesozoic crocodyliforms.

“Our work demonstrates that extinct crocodyliforms had an incredibly varied diet,” says Melstrom. “Some were similar to living crocodylians and were primarily carnivorous, others were omnivores and still others likely specialised eating plants.

“The herbivores lived on different continents at different times, some alongside mammals and mammalian relatives, while others did not. This suggests that an herbivorous crocodyliform could be successful in a variety of environments!”

Melstrom says they are continuing to reconstruct the diets of extinct crocodyliforms, including fossilised species that are missing teeth. He also wants to understand why the extinct relatives of crocodiles diversified so radically after one mass extinction but not another, and whether dietary ecology could have played a role.

⮝ Keegan Melstrom, the study’s lead author, with the fossil jaw of *Brachychampsa* and 3D prints of other extinct crocodyliforms (blue). The teeth of *Brachychampsa* are bulbous, suggesting a diet of hard-shelled animals, whereas many others are complex and imply a diet made up of plants. Photo courtesy Natural History Museum of Utah.

Further information

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Deep sea dives

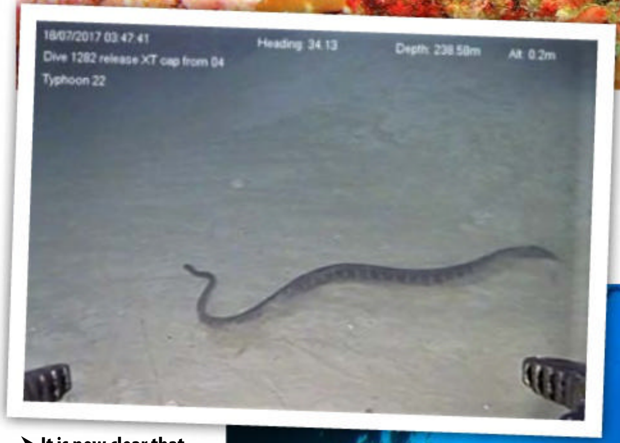
Sea snakes, which are best-known from shallow tropical waters, have recently been recorded swimming at depths of approximately 250m (820ft) in the deep-sea 'twilight zone', comprehensively smashing the previous depth record of 133m (436ft) that existed for these marine reptiles.

Footage of two sea snakes taken at this new depth has been provided to University of Adelaide researchers by INPEX Australia, an exploration and production company operating in the Browse Basin off the Kimberley coast of Australia. Both individuals appeared to belong the same species.

Sea snakes are found in tropical waters of the Indian and Pacific Oceans and are typically associated with shallow water habitats like coral reefs and river estuaries. "Sea snakes were thought only to dive between a maximum of 50 to 100 metres (165-330ft) because they need to swim regularly up to the surface of the sea to breathe air, so we were very surprised to find them so deep," admits Dr Jenna Crowe-Riddell, from the University's School of Biological Sciences.

▲ Sea snakes are typically associated with tropical reefs, where prey is readily available.

Photo courtesy Rich Carey/www.shutterstock.com



◄ Record-setting dive of a sea snake swimming at 240m (780ft) in the deep-sea 'twilight zone'.

Photo courtesy INPEX-operated Ichthys LNG Project.

➤ It is now clear that sea snakes can dive into the abyss.

Photo courtesy Rich Carey/ www.shutterstock.com

New questions raised

Oceanic depths between 200 and 1000 metres (656-3280ft) encompass the mesopelagic zone, sometimes called the 'twilight zone' because only a small amount of light reaches that depth. These record-setting dives raise new questions about the ecology and biology of sea snakes. The snakes were filmed using a remotely operated vehicle or 'ROV' undertaking work for the INPEX-operated Ichthys LNG Project.

"We have known for a long time that sea snakes can cope with diving sickness known as 'the bends' using gas exchange through their skin," Dr Crowe-Riddell explains. "But I never suspected that this ability would allow sea snakes to dive to deep-sea habitats."

"In some of the footage, the snake is looking for food by poking its head into burrows in the sandy sea floor, but we don't know what type of fish they're eating or how they sense them in the dark," she adds.

"Observations of sea snakes have typically been limited to shallow water habitats that are easily surveyed. But this discovery shows what can be achieved through industry-university collaboration," says co-author Dr Kate Sanders, ARC Future Fellow in the University's School of Biological Sciences.

▼ It used to be thought that sea snakes needed to remain close to the surface, so they come up to breathe easily, as they do not have gills.

Photo courtesy Anita Kainrath/ www.shutterstock.com

Further information

Jenna M. Crowe-Riddell, Blanche R. D'Anastasi, James H. Nankivell, Arne R. Rasmussen, Kate L. Sanders. **First records of sea snakes (Elapidae: Hydrophiinae) diving to the mesopelagic zone (>200 m).** *Austral Ecology*, 2019; DOI: 10.1111/ aec.12717

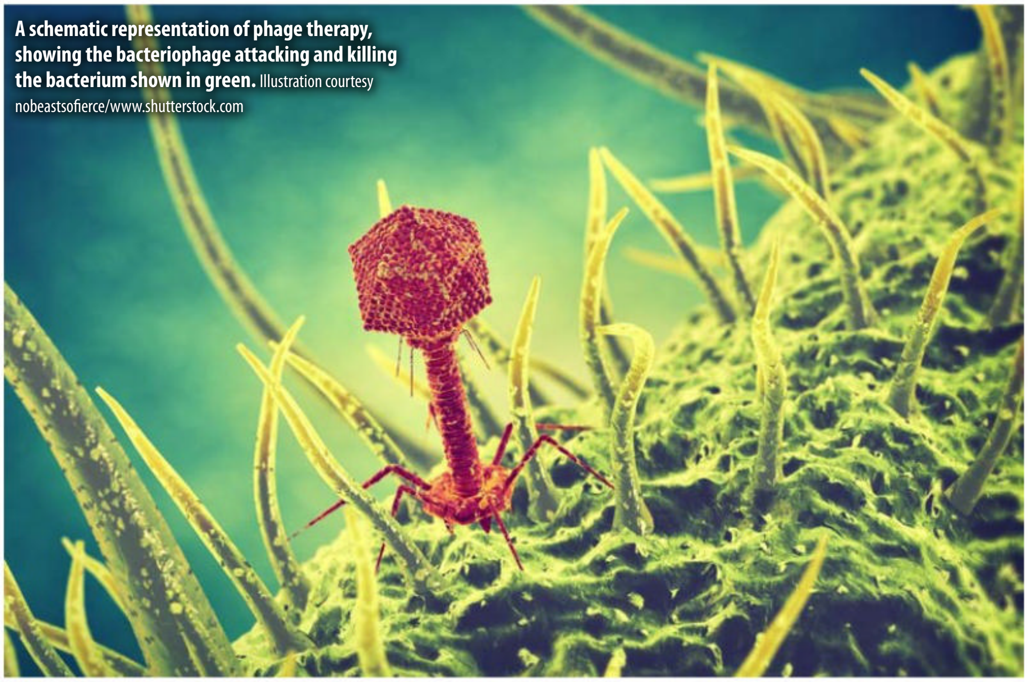
Good viruses and bad bacteria

A world-first study at Australia's James Cook University has found an alternative to antibiotics for treating bacterial infections in green sea turtles.

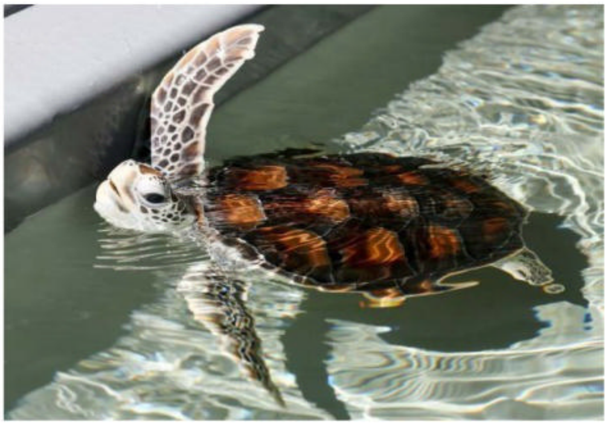
Researchers at the JCU Turtle Health Research Facility have conducted a first-of-its-kind study using what is known as phage therapy, as an option to combat bacterial infections in green sea turtles.

Phage therapy uses so-called 'good viruses' (bacteriophages) that occur naturally in the environment and kill bacteria. "Green turtles rely on 'good bacteria' in their gut to extract nutrients from food," says Dr Robert Kinobe, one of the researchers involved in the study. "This creates a challenge when it comes to treating bacterial infections because if we administer antibiotics, it can destroy the beneficial bacteria and make the turtle's health worse."

Researchers at the JCU Turtle Health Research Facility applied 'good viruses' to green sea turtles and found that these were successful in eliminating the targeted 'bad bacteria' without hampering the non-targeted 'good bacteria'. "This shows that phage therapy can be safe and effective enough to manipulate or treat targeted bacteria in green sea turtles," explains Dr Kinobe.



A schematic representation of phage therapy, showing the bacteriophage attacking and killing the bacterium shown in green. Illustration courtesy nobeastsofierce/www.shutterstock.com



One of the turtles used in this trial, which revealed a way to overcome the issue of antibiotic resistance. Photo courtesy Bethany Keats, JCU Media.

A resistance issue

A further complication, previously identified by the JCU Turtle Health Research Facility, is the existence of antibiotic-resistant bacteria in the guts of green sea turtles, which are found in several locations along the Queensland coast. "Antimicrobial resistance is one of the most critical issues we face, which is why this finding of an alternative to antibiotics is so important," adds co-researcher Dr Lisa Elliott.

"Bacteriophages and phage therapy have already been suggested as an alternative for antibiotics in humans, but we also need to investigate its scope for treatment in animals. It does, however, open the door for the further use of phage therapy as an alternative to antibiotics when treating bacterial infections in turtles and other marine animals.

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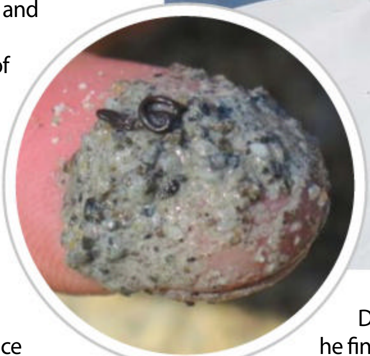
This trial has shown that it is possible to treat turtles suffering from bacterial infections successfully using phage therapy. Photo courtesy alisafarov/www.shutterstock.com

A super–cool invertebrate

Scot Hotalilng on the hunt for iceworms. Photo courtesy Scot Hotalilng/ Washington State University.



One of the remarkable ice worms. Photo courtesy Scot Hotalilng/ Washington State University.

The ice worm is one of the largest organisms that spends its entire life in ice, and Washington State University scientist Scot Hotalilng is one of a tiny number of people on the planet studying it. His new research confirms that ice worms in the interior of British Columbia have evolved into what may be a genetically distinct species from those found in Alaska.

An ice worm resembles the common earthworm, but is smaller and darker in colour. What sets the ice worm apart from other members of the *Mesenchytraeus* genus, however, is its remarkable ability to live its entire life in glacial ice.

Millions, perhaps hundreds of millions, of ice worms can be seen wriggling to the top of glaciers from the Chugach Mountains in southeast Alaska to the Cascade Volcanoes of Washington and Oregon during the summer months. In the fall and winter, ice worms subsist deep beneath the surface of glaciers where temperatures stay around freezing.

An inspirational encounter

Hotaling's interest in ice worms began back in 2009 while he was working as a mountaineering ranger on the high elevation slopes of Mt. Rainer. He was climbing here at three o'clock in the morning when he noticed a lot of small, black worms crawling around on the surface of a glacier.

"I wasn't even a biology undergraduate then, but I remember being so fascinated by the fact that there is this worm that can live in a glacier," he explains. "It is not a place where we think of life being able to flourish and yet these worms can be present at densities of 200 in each square metre (11 square feet), being so numerous you can't walk without stepping in them."

Hotaling was inspired to go back to academic study and earned a doctorate in biology at the University of Kentucky where he studied how climate change is affecting mountain biodiversity.

Mount Rainier, where Scot Hotalilng first encountered the tiny invertebrates that were to change his life.
Photo courtesy William Stanbro/www.shutterstock.com

During the summer of 2017, he finally got the opportunity to circle back and do some research on the ice worm when he arrived in Pullman to work in the laboratory of Associate Professor Joanna Kelley, who specialism is evolutionary genomics and extremophile life-forms.

"In the Kelley lab, we study organisms that have evolved to live in places that are inhospitable to pretty much everything else," Hotaling explains. "Determining the evolutionary mechanisms that enable something like an ice worm to live in a glacier or bacteria to live in a Yellowstone hot spring is a really exciting way to learn about what is possible at the boundaries of evolution. That's where we are working now, understanding the evolution of ice worms."

An unexpected find

Hotaling and colleagues extracted and sequenced DNA from 59 ice worms collected from nine glaciers across most of their geographical range. Their analysis revealed a genetic divergence between populations of ice worms that are north and west and south and east of the Coast Mountains of British Columbia.

The researchers predict that this deeper split into two genetically distinct ice worm groups occurred as a result of glacial ice sheets contracting around a few hundred thousand years ago, isolating worms in the Pacific Northwest from their counterparts in Alaska.

The most surprising finding of the study came from Vancouver Island, however, where Hotaling and colleagues identified a single ice worm that is closely related to a separate population of ice worms located 1930km (1200ml) away in southern Alaska.

"At first we thought there has to be some kind of error in the analysis or prep methods but upon further investigation, we confirmed our initial results," Hotaling says. "These are worms isolated on mountain tops and there is no explanation for how they covered that gap than on, or perhaps within, migrating birds."

A helping hand

The research illuminates an important relationship between two of the few large organisms that inhabit North America's high elevation alpine ecosystems: the ice worm and the grey-crowned rosy finch (*Leucosticte tephrocotis*) which nests there.

A grey-crowned rosy finch seen feeding on ice worms. Photo courtesy Scot Hotalilng/Washington State University.

"We knew that ice worms were an important source of food for the birds but we didn't know until now that the birds are also likely very important for the ice worms," Hotaling admits. "If you are super isolated like an ice worm, you could easily become inbred. But if birds are bringing little bits of new diversity to your mountaintop glacier, that could be really good for you."

The researchers believe the genetic intermingling is the result of birds eating the glacier-bound worms (or their eggs) at one location and then dropping them off at another as they migrate up and down the west coast.

"If you are a worm isolated on a mountain-top glacier, the expectation is you aren't going anywhere," admits Hotaling, a postdoctoral biology researcher. "But low and behold, we found this one ice worm on Vancouver Island that is super closely related to ice worms in southern Alaska. The only reasonable explanation we can think of to explain this is birds."

Further information

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Skin bacteria can protect frogs from attack

Bacteria living on the skin of frogs could save them from a deadly virus, new research suggests. Ranavirus kills large numbers of European common frogs (*Rana temporaria*) – the species most often seen in UK ponds – and is one of many threats facing amphibians worldwide.

Scientists from the University of Exeter and ZSL's Institute of Zoology compared the bacteria living on frogs (which is known as their "microbiome") with groups which have a varying history of ranavirus outbreaks. They found that populations of frogs with a history of outbreaks had a "distinct" skin microbiome when compared with those where no outbreaks had occurred.

Disease influences

"Whether a population of frogs becomes diseased might actually depend on the species of bacteria living on their skin," says Dr Lewis Campbell. "Ranavirus is widespread, but its presence in the environment doesn't necessarily mean frogs become diseased – there appears to be some other factor or factors that determine whether this occurs.

"The skin is often the initial infection point in ranavirus, and the first stage of the disease can be skin sores. It's possible that the structure of a frog's microbiome – the mix of bacteria on its skin – can inhibit the growth and spread of the virus so it can't reach a level that causes disease.

"While the results of our study demonstrate a clear link between the microbiome of frog skin and disease outbreaks, further research will be needed to understand the exact mechanisms involved," he adds.

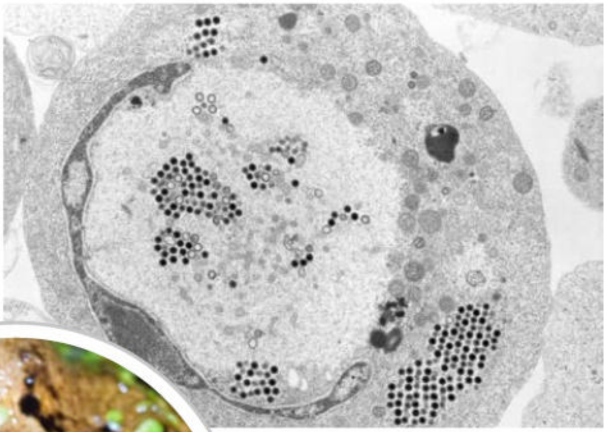
Scientific investigations

Laboratory trials help to establish whether a history of ranavirus infection causes the microbiome differences, or if these are pre-existing distinctions that predispose some populations to infection. The scientists tested the skin bacteria of more than 200 wild adult European common frogs from 10 populations.

They found that the microbiome of individual frogs usually most closely resembles those of others in the same population (meaning those living in the same geographical area), but that frogs with the same disease history were more similar to each other than to populations having the opposite disease history.

New hope

Even though amphibians can partially "curate" their microbiome by producing proteins that benefit specific bacteria, they are limited to those bacteria which are available in their environment. Ranavirus can wipe out entire common frog populations and, though the new findings need further investigation, the researchers hope their work could help the species.



⮝ A highly magnified electron micrograph of a cell infected with ranaviruses, visible as the clustered dark hexagons here. Photo courtesy Electron Microscopy Unit AAHL, CISRO/CC-BY-SA 3.0.

Dr Xavier Harrison explains: "There's growing evidence that skin bacteria may protect amphibians from lethal pathogens such as chytrid fungus, and that we can develop cocktails of probiotic bacteria to prevent vulnerable individuals from contracting disease. Our work suggests that given enough effort and research, similar probiotic therapies may be effective against ranavirus."

⮝ Individual bacterial populations present on the skin of frogs influence their susceptibility as to whether they are likely to become infected with ranavirus, according to this new research. Photo courtesy Chrispo/www.shutterstock.com

Further information

Lewis J. Campbell, Trenton W. J. Garner, Kevin Hopkins, Amber G. F. Griffiths, Xavier A. Harrison. **Outbreaks of an Emerging Viral Disease Covary With Differences in the Composition of the Skin Microbiome of a Wild United Kingdom Amphibian.** *Frontiers in Microbiology,* 2019; 10 DOI: 10.3389/fmicb.2019.01245

⮝ The risk of infection is greatest when frogs cluster together in spring, coming together for spawning. This is also the stage at which they may sustain minor injuries, making it easier for the virus to gain access to the body. Photo courtesy Karin Jaehne/www.shutterstock.com

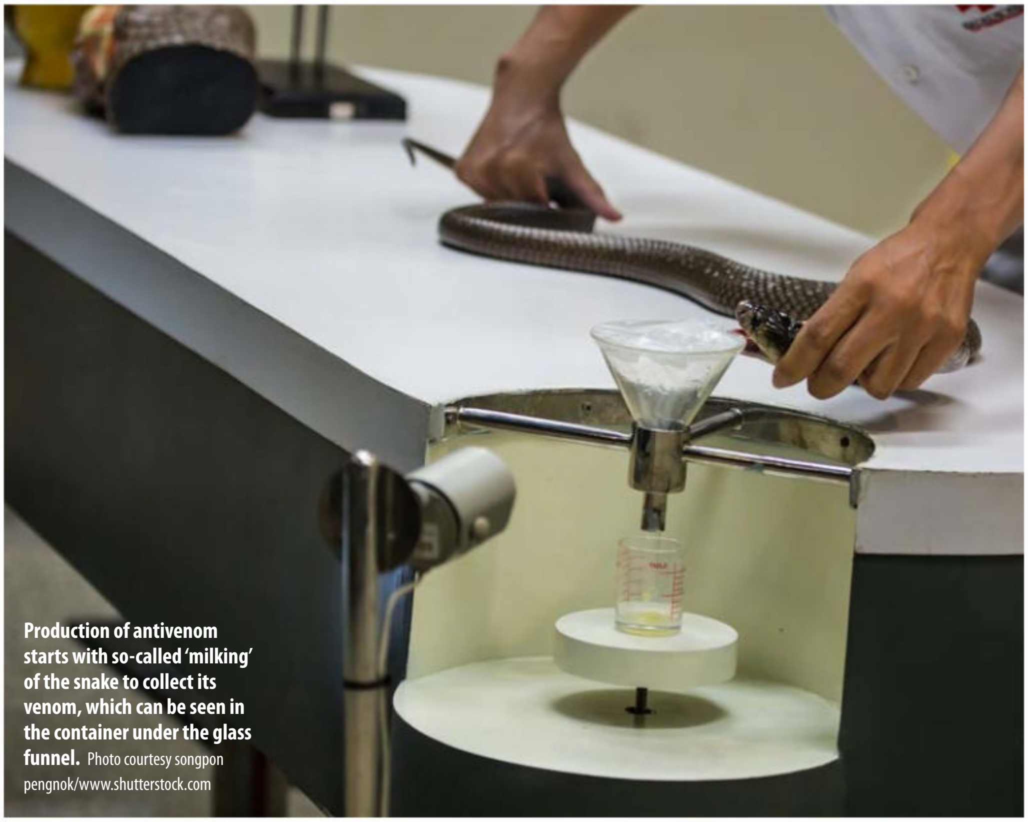
⮝ Could beneficial bacteria on the skin of amphibians be manipulated to help defend them against chytrid fungus and ultimately be harnessed to provide protection? Members of the *Atelopus* genus such as the stumpfoot toad (*A. hoogmoedi*) are amongst those that have been very badly affected by chytrid fungus over recent years. Photo courtesy reptiles4all/www.shutterstock.com

New solutions sought to snake bites

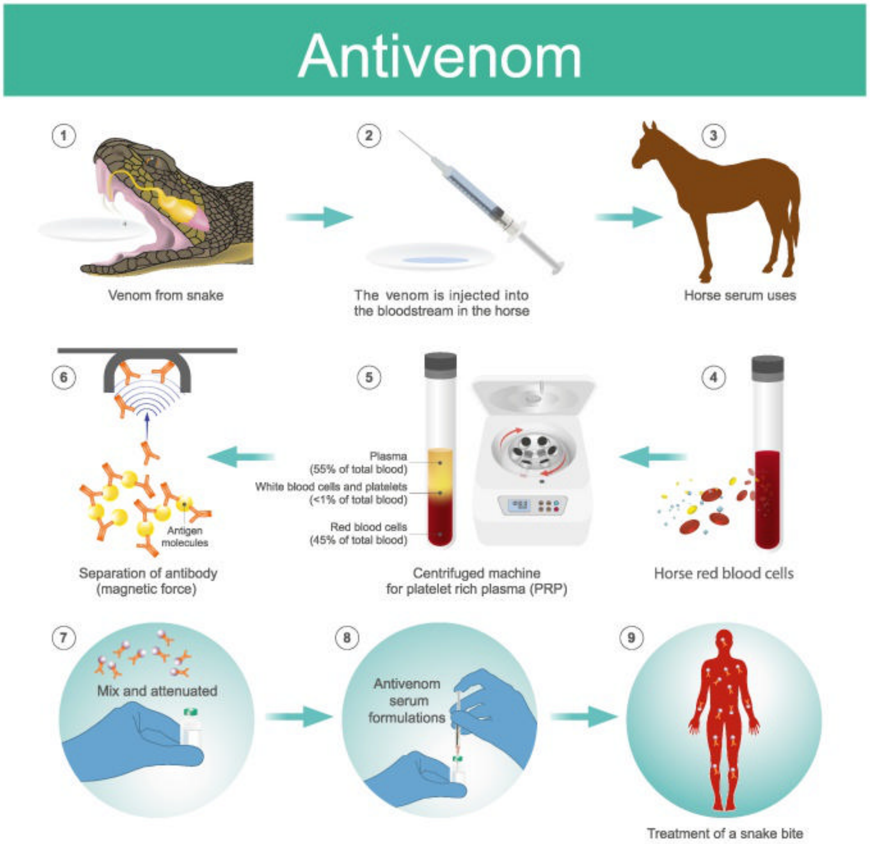
According to the World Health Organisation, about 100,000 people die from venomous snake bites every year. Many of these fatalities occur in rural areas in developing countries that lack access to antivenoms. That's why researchers are looking for new snakebite antidotes that are easier to make and use in remote areas.

The current approach for making antivenoms dates back to the early 20th century and involves milking a venomous snake and then immunising horses with the diluted venom. Over a period of several months, this then triggers the horses' immune systems to start making antibodies against the venom molecules, which are then extracted from the blood and purified.

In addition to being slow and expensive, however, the technique also yields horse proteins that could trigger allergic reactions in people. Moreover, the antivenoms require refrigeration and trained personnel to administer them, which are often unavailable in rural areas.



Production of antivenom starts with so-called 'milking' of the snake to collect its venom, which can be seen in the container under the glass funnel. Photo courtesy songpon pengnok/www.shutterstock.com


Antivenom
1
Venom from snake
2
The venom is injected into the bloodstream in the horse
3
Horse serum uses
6
5
4
Plasma (55% of total blood)
White blood cells and platelets (<1% of total blood)
Red blood cells (45% of total blood)
Antigen molecules
Separation of antibody (magnetic force)
Centrifuged machine for platelet rich plasma (PRP)
Horse red blood cells
7
Mix and attenuated
8
Antivenom serum formulations
9
Treatment of a snake bite

⮝ This diagram shows how antivenom is currently made. The aim is to make the process quicker and safer, as well as avoiding the need to refrigerate it. Artwork courtesy Studio BKK./www.shutterstock.com

New approaches

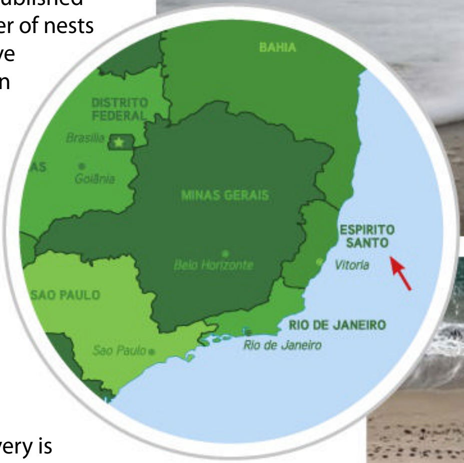
Researchers are therefore now exploring alternatives to conventional antivenoms that could overcome these problems. Ophirex, Inc. is investigating a small molecule, called varespladib, that inhibits a venom enzyme called phospholipase A2. This enzyme causes paralysis, bleeding and muscle destruction in snake bite victims. Unlike current antivenoms, varespladib is inexpensive and does not require refrigeration.

Other researchers are trying to make human monoclonal antibodies to address the dangerous components of snake venoms. These could be easier to produce and less allergenic in effect than horse antibodies. Some scientists say that improving the current process to provide more high-quality antivenoms to the developing world may be the best approach to combating snake-bites, which kill thousands of people worldwide, particularly in these areas.

Photo courtesy ccarbill/www.shutterstock.com

Leatherbacks start to bounce back in Brazil

A female leatherback turtle heads back to sea after egg-laying.
Photo courtesy Brendan Delzin/www.shutterstock.com



⮝ Espirito Santo lies to the north of Rio de Janeiro.
Illustration courtesy pingebat/www.shutterstock.com

Brazil's leatherback turtles are making a "gentle recovery" after 30 years of conservation efforts, new research shows. Scientists have been studying nesting sites in the state of Espírito Santo in eastern Brazil, which is the only place in the south-west Atlantic where leatherbacks regularly nest. Data collected on this small population and just published showed the average number of nests rose from 25.6 in the first five years of the period to 89.8 in the final five years.

"The numbers vary year by year, but overall we have seen an increase in the number of leatherback nests in Espírito Santo over the past 30 years," says Dr Liliana Poggio Colman, of the Centre for Ecology and Conservation, based at Exeter's Penryn Campus in Cornwall. "This gentle recovery is probably due, at least in part, to local conservation efforts started by Projeto TAMAR during the 1980s. Our study revealed a significant decrease in the size of the turtles breeding on these beaches, suggesting that new females are joining the breeding population."

Dr Poggio Colman says: "We are encouraged by what we have found, but this is a small population – fewer than 20 nesting females per year, each laying several clutches – so their conservation will remain a concern."

⮝ Distinctive pattern of tracks on the beach can help to highlight the presence of nesting leatherbacks in the area. Photo courtesy Thomas Barrat/www.shutterstock.com

⮟ A baby leatherback turtle scrambles into the ocean. The distinctive ridges running along the shell are apparent even at this early age.
Photo courtesy IrinaK/www.shutterstock.com

Threats remain

The researchers, including staff from the Brazilian sea turtle conservation programme TAMAR-ICMBio, believe local conservation efforts have contributed to this increase. But they also highlight the fact that conservation of this population is still a concern for a variety of reasons, including climate change, pollution, coastal development and "bycatch" (which is the term used to describe the accidental catching of turtles by people in search of fish).

Throughout the study period, nests were concentrated in the southern part of the study area, which extended over 160km (100ml), with the protection of core nesting areas being key for the effective conservation of this population.

"By chance, the team was in the field when a major spill of waste mining material impacted in the area in 2015. Average hatching success has, however, remained fairly steady at about 66%," adds Professor Brendan Godley, another member of the research team.

Further information

LP Colman, JCA Thomé, AdP Almeida, C Baptistotte, PCR Barata, AC Broderick, FA Ribeiro, L Vila-Verde, BJ Godley. **Thirty years of leatherback turtle *Dermochelys coriacea* nesting in Espírito Santo, Brazil, 1988-2017: reproductive biology and conservation.** *Endangered Species Research*, 2019; 39: 147 DOI: 10.3354/esr00961

How the dragon got its frill

In the film *Jurassic Park*, when the computer programmer Dennis Nedry attempts to smuggle dinosaur embryos off the island, he gets attacked and killed by a mid-sized dinosaur that erects a frightening neck frill. This fictional dinosaur was clearly inspired by the so-called frilled dragon (*Chlamydosaurus kingii*) that lives today in northern Australia and southern New Guinea.

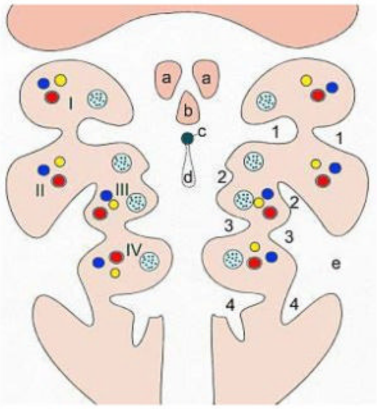
These lizards have a large disc of skin that sits around their head and neck. This frill is usually folded back against the body, but can spread open in a spectacular fashion to scare off predators and competitors. Folding of the left and right sides of the frill occurs at three pre-formed ridges. But it remains unclear which ancestral structure evolved to become the dragon's frill, and how the ridges in the frill form during development.

Recycling gills

A multidisciplinary team led by Michel Milinkovitch, Professor at the Department of Genetics and Evolution of the UNIGE Faculty of Science and Group Leader at the SIB Swiss Institute of Bioinformatics, has now shown that the dragon's frill, as well as bones and cartilages that support it, develop from the branchial (or pharyngeal) arches. These are a series of bands of tissue in the embryo that evolved to become the gill supports in fish, and that now give rise to multiple structures in the ear and neck of land vertebrates.

▲ A frilled lizard with its frill fully raised, in an intimidatory gesture.

Photo courtesy Matt Cornish/www.shutterstock.com



◀ The branchial or pharyngeal arches of the embryo, as seen in cross-section. These embryonic structure ultimate shape the neck frill of these lizards.

Artwork courtesy Uwe Gille/Wikipedia/CC-BY-SA 3.0

In most species, the second branchial arch will eventually fuse with the arches behind it. But in the frilled dragon, this arch continues instead to expand, leading to the formation of the dragon's spectacular frill. "These changes in the development of gill arches highlight how evolution is able to 'recycle' old structures into new forms playing different roles," enthuses Michel Milinkovitch.

A primarily mechanical impact

As the frill develops, the front side of the skin forms three successive folds, which make up the pre-formed ridges. Studying the formation of these ridges, the Swiss team found that they do not emerge from increased growth at the folding sites, but from physical forces – whereby the growth of the frill is constrained by its attachment to the neck. This causes the top layer to buckle, creating the folds of the frill.

"We then simulated this process in a computer model and discovered that we could trace how the folds develop in the frills of the real lizard embryos," continues Michel Milinkovitch. These results provide further evidence that physical processes, (aside from genetic influences), can shape tissues and organs during an embryo's development, to dramatic effect.

◀ The way that the frill lies is determined by the pre-formed ridges on each side of the body.

Photo courtesy of Bildagentur Zoonar GmbH/www.shutterstock.com

INSET: The colour of the frill is variable, being influenced by that of the individual. It gives these lizards a very dinosaur-like appearance.

Photo courtesy Matt Cornish/www.shutterstock.com

Further information

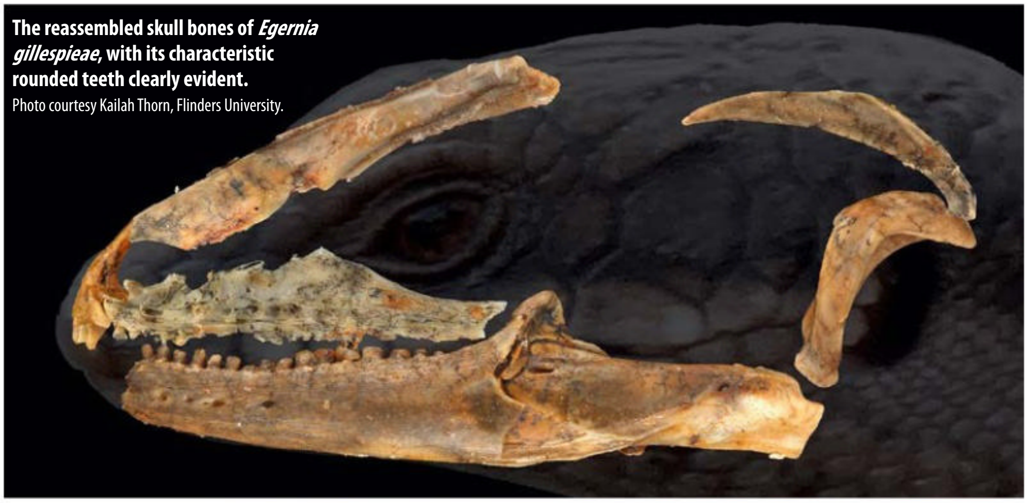
Sophie A Montandon, Anamarija Fofonjka, Michel C Milinkovitch. **Elastic instability during branchial ectoderm development causes folding of the *Chlamydosaurus* erectile frill.** *eLife*, 2019; 8 DOI: 10.7554/eLife.44455

Blue-tongue ancestor had round teeth

Reconstruction of the most complete fossil lizard yet found in Australia, reveals a creature which was equipped with a robust crushing jaw and was remarkably similar to modern lizards. Named *Egernia gillespieae*, it is a 15 million year old relative of modern blue-tongues and social skinks.

A new study led by Kailah Thorn from Flinders University in Adelaide, South Australia, combined the anatomy of living fossils with DNA data to put a time scale on the family tree of Australia's 'social skinks'. "This creature looked like something in-between a tree skink and a blue-tongue lizard. It would have been about 25cm (10in) long, and unlike any of the living species today, it was equipped with robust crushing jaws," says Ms Thorn.

The results have revealed that Australia's blue-tongue lizards split from *Egernia* as early as 25 million years ago. "The new fossil is unusually well-preserved, with much of the skull, and some limb bones, all from a single individual," she explains. "It belongs to the genus *Egernia*, with modern species in this group often being called 'social skinks'. They are known for living in family groups, sharing rocky outcrops and hollow tree stumps."



The reassembled skull bones of *Egernia gillespieae*, with its characteristic rounded teeth clearly evident.
Photo courtesy Kailah Thorn, Flinders University.

➤ The internationally significant Riversleigh World Heritage fossil site, where this discovery was made.
Photo courtesy marsronny/ www.shutterstock.com

A rare find

Remarkably similar to modern social skinks, *E. gillespieae* does, however, have rounded, crushing teeth and a deep, thick jaw. Its fossilised remains, unearthed from the Riversleigh World Heritage fossil deposits in northwest Queensland, were named after Dr Anna Gillespie, a UNSW palaeontologist responsible for preparing many of the spectacular fossils that have been unearthed in that area.

"I have been preparing the Riversleigh fossil material for quite a few years now and lizard bones are rare elements. When the jaw appeared and was quickly followed by associated skull elements, I had a good feeling it would be a significant addition to the Riversleigh reptile story, as turned out to be the case," says Dr Gillespie.

⮟ The dental structure of a contemporary blue-tongue skink, with its teeth being far less prominent.
Photo courtesy Peter Waters/ www.shutterstock.com

Further information

Kailah M. Thorn, Mark N. Hutchinson, Michael Archer, Michael S. Y. Lee. **A new scincid lizard from the Miocene of Northern Australia, and the evolutionary history of social skinks (Scincidae: Egerniinae).** *Journal of Vertebrate Paleontology*, 2019; e1577873 DOI: 10.1080/02724634.2019.1577873

Stessed tadpoles less likely to survive as adult frogs

The level of activity of northern red-legged frogs appears to be pre-determined by their experiences as tadpoles.
Photo courtesy Amy Olson/www.shutterstock.com

New Oregon State University (OSU) research shows that juvenile northern red-legged frogs (*Rana aurora*) that have experienced climate-related stress as tadpoles are less likely to move on land, putting their survival at risk. According to Evan Bredeweg, an OSU aquatic ecologist, these findings indicate changing patterns of precipitation and drought will influence the distribution and persistence of animals that live in freshwater habitats in future.

"This is an understudied but vital stage in their lifecycle, where frogs are moving from one habitat to the next and the influence of the aquatic environment and the terrestrial environment act together on this one part of their life history," explains Bredeweg, who works in the area of wildlife ecology in OSU's College of Agricultural Sciences. "We found that stress on tadpoles is carried over through metamorphosis into how the frogs move, in addition to the stress of being on land for the first time."

Lifestyle

The northern red-legged frog is native to the west coast of North America, ranging from southwestern British Columbia to northern California. Populations are declining in Oregon, where the study was based. These frogs spend the first part of their life in ponds but after metamorphosis, they move to upland forested areas where they mature and live as adults. The young frogs are only about 20mm (0.75in) in length.

"They are tiny, they are vulnerable to predators and desiccation, and they are moving this way for the first time," Bredeweg says. The frogs subsequently make the return journey back to their ponds when they are large enough to breed. Individuals have been known to disperse as far as 2.5km (1.5ml), but most stay within 100m (328ft) of their pond.

A red-legged frog just completing its metamorphosis from a tadpole, ready to head off for a terrestrial existence.
Photo courtesy Darren J. Bradley/ www.shutterstock.com

How the study was carried out

For the study, the researchers retrieved eggs from three ponds in the Willamette Valley, hatched the tadpoles in a laboratory, and placed them in outdoor tanks filled with water. Two weeks later, water levels in half of the tanks were drawn down by 4l (7pt) every week until only 5-7.5cm (2-3in) of water remained, while the other tanks remained full with 100l (22gal).

This lowering of the water level was meant to simulate an ephemeral pond rapidly losing water in conditions that are warmer and drier than normal. After metamorphosis, each young frog was measured and marked with a unique colour tag, then transferred to an outdoor terrarium.

Frogs from the ephemeral conditions metamorphosed at a smaller size but grew faster than the control frogs after being moved to the terrariums. But the frogs that couldn't catch up with their normal-sized counterparts were not capable of traveling as far on land.

So as to track the frogs' movements, the researchers constructed four 20m (65ft) runways on smooth topsoil. Half of the runways were doused with water immediately before frogs were released here, while the other half remained dry

⌃ **After spawning, these frogs head off away from their breeding ponds, often travelling relatively long distances.** Photo courtesy Randimal/www.shutterstock.com

– except at the release point. The dry runways were meant to be physiologically taxing on the young frogs.

What was revealed

The runway experiment exposed both the probability of the frog moving away from the start location and its movement distance. Larger frogs were more likely to move down the runway and were able to travel a greater distance than smaller individuals. In addition to the reactions based on size, dry runway conditions reduced the probability of frogs moving from the start location.

In an interesting and potentially positive outcome, the frogs that did move on the dry runway traveled farther. "These frogs showed an ability to be responsive to the environment, which means they could respond appropriately in drier conditions," notes OSU associate professor Tiffany Garcia. "But overall, this is a species that relies on producing many offspring and only a few will survive, especially at a young age. A small shift in that percentage could mean major consequences in the long run."

⌃ **Size influenced the distance that the frogs travelled in this experiment.** Photo courtesy Randy Bjorklund/www.shutterstock.com

Further information

Evan M. Bredeweg, Jenny Urbina, Anita T. Morzillo, Tiffany S. Garcia. **Starting on the Right Foot: Carryover Effects of Larval Hydroperiod and Terrain Moisture on Post-metamorphic Frog Movement Behavior.** *Frontiers in Ecology and Evolution*, 2019; 7 DOI: 10.3389/fevo.2019.00097

Sea snakes that can't drink sea water

Surrounded by salty water, sea snakes sometimes live a thirsty existence. Previously, scientists thought that they were able to drink seawater, but recent research has shown that they need to access freshwater. A new study led by Harvey Lillywhite, professor of biology of the University of Florida, has revealed that sea snakes living where there is drought relieve their dehydration as soon as the wet season hits.

The snakes do this by obtaining freshwater from so-called "lenses" that form on the surface of the ocean during heavy rain. These are events in which the salinity at the surface decreases enough for the water to become drinkable.

The yellow-bellied sea snake (*Hydrophis platurus*) is the only reptile in the order Squamata that lives in the open sea. It has one of the largest geographic distributions of any vertebrate species. Given its broad range and seafaring existence, during the dry season (which lasts for 6-7 months at the study site in Costa Rica), it has no access to freshwater.

Rainfall matters

How these snakes survive in regions of drought seems to hinge upon access to freshwater lenses, but little is known about how marine vertebrates react to or consume rainfall. "This study contributes to a fuller understanding of how pelagic sea snakes, and possibly other marine animals, avoid desiccation following seasonal drought at sea," says Lillywhite.

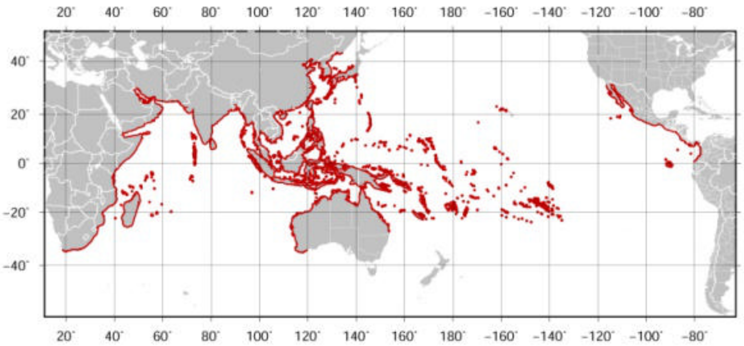
The researchers captured 99 sea snakes off the coast of Costa Rica (interestingly, these snakes have never been observed in estuaries) and offered them freshwater in a laboratory environment. The team happened to be there just as six months of drought broke and the rainy season began. They found that only 13 percent of snakes captured after the rainfall began accepted the offer, compared to 80 percent of those captured beforehand. The assumption is that the rainfall must therefore have quenched their thirst.

The study continues many years of work by Lillywhite investigating snake biology and that of tree frogs too. "How yellow-bellied sea snakes locate and harvest precipitation is important in view of the recent declines and extinctions of some species of sea snake," he adds. The question remains, however, as to how climate change and its effects on rainfall patterns could impact on sea snakes and their populations in different areas?

Yellow-bellied sea snakes live exclusively in the marine environment, occasionally being encountered as here on a beach.
Photo courtesy RobHamm/www.shutterstock.com

◀ A yellow-bellied sea snake on a Costan Rican beach. They are known to be able to survive droughts lasting as long as seven months.
Photo courtesy Aloaiza/CC BY-SA 3.0.

▶ These snakes can vary significantly in appearance. This is a yellow example, spotted off the Pacific (western) coast of Costa Rica.
Photo courtesy Gabriele Kothe-Heinrich/CC BY-SA 3.0.



▲ The yellow-bellied sea snake has a huge range.
Map courtesy the author of the work and the IUCN Red List spatial data/CC BY-SA 4.0.

Further information

Harvey B. Lillywhite, Coleman M. Sheehy, Mark R. Sandfoss, Jenna Crowe-Riddell, Alana Grech. **Drinking by sea snakes from oceanic freshwater lenses at first rainfall ending seasonal drought.** *PLOS ONE*, 2019; 14 (2): e0212099 DOI: 10.1371/journal.pone.0212099

Bright baby blue-tongues

A baby blue-tongue skink, disturbed in amongst the leaf litter where it was hiding, reacts aggressively by flaring its tongue.
Photo courtesy King Ropes Access/www.shutterstock.com

Young Australian eastern blue-tongue skinks (*Tiliqua scincoides*) are every bit as clever as adults, researchers have discovered. This is probably a reflection of the fact that life is hard for baby blue-tongues. As soon as they are born, they are on their own, with neither parental support nor protection.

Adults of the species can grow to 60cm (24in) long and enjoy the benefits of thick scales and a powerful bite, but the young are much smaller and thus more vulnerable to predation. This means they have to learn fast if they are going to survive.

▼ These skinks use their unusually long and blue-coloured tongue as a way of deterring predators, by initially shocking them with its appearance. This juvenile Centralian blue-tongue skink (*Tiliqua multifasciata*) was photographed in the arid surroundings of the Pilbara region of Western Australia.
Photo courtesy meyblume/www.shutterstock.com

A ground-breaking study

In order to establish just how smart baby blueys are, researchers Birgit Szabo and Martin Whiting from Australia's Macquarie University, together with colleagues from the Australian National University, the University of New South Wales, and St Andrews University in Scotland, put wild-caught adult and juvenile individuals through a series of tasks designed to test their cognitive abilities.

A dozen adults, all over two years old, were used in the investigation, along with 16 captive-born juveniles, all aged between 23 and 56 days. "In all the tests, the young lizards performed every bit as well as the adults," says Szabo. "This indicates that the young learn at adult levels from a very early age."

The study is the first to directly compare adult and juvenile flexible learning in a reptile species. It opens the way for many more comparative investigations of this type, into what is clearly an area of behaviour in reptiles which requires further investigation.

Further information

Birgit Szabo, Daniel W.A. Noble, Richard W. Byrne, David S. Tait, Martin J. Whiting. **Precocial juvenile lizards show adult level learning and behavioural flexibility.** *Animal Behaviour*, 2019; 154: 75 DOI: 10.1016/j.anbehav.2019.06.003

Mixed rattlesnake venom

The impact of the venom of the Mojave rattlesnake varies significantly through its range, which includes the Joshua Tree National Park, seen here. Photo courtesy HeavyT Photography/www.shutterstock.com

The Mojave rattlesnake (*Crotalus scutulatus*), living in the deserts of the southwestern United States and central Mexico, is characterised by its lethal venom that can either shut down your body's nervous system or attack your blood clotting mechanism. Clemson University researchers say which one is employed depends on where you are located when you are bitten.

Based on snakebite documentation from Mojave rattlesnakes extending as far back as the 1920s, it was thought that these feared pit vipers only had neurotoxic venom, comprised of a cocktail of enzymes and peptides that disrupts neurons and paralyses the nervous system.

However, a few cases on record were curiously different, with patients displaying different symptoms following a bite. These included tissue damage, disorientation and impaired blood clotting. After several decades of investigation, scientists later credited these symptoms to a second venom type in the Mojave rattlesnake: this is known as haemorrhagic, and it acts by destroying tissues in the body.

⮝ Jason Strickland milks a Mojave rattlesnake for its venom. Photo courtesy Gregory Territo.

To discover which venom type occurs where, herpetologists have been collecting data on Mojave rattlesnakes in the southwestern region. However, it wasn't until a recent publication by Clemson College of Science postdoctoral researcher Jason Strickland and professor of biological sciences Christopher Parkinson that the extent of the distribution became better understood. Their findings show a peculiar variability in the species.

⮝ The colouration of this snake also varies through its range. It is known as the mojave green rattlesnake in some areas, because of the slightly greenish tinge to its appearance, although there appears to be no direct link between it colouration and venom type. Note the rattle at the end of the tail here as well. Photo courtesy Vibe Images/www.shutterstock.com

"Prior to this paper, it was thought that haemorrhagic venom was really rare and it was only found in Mojave rattlesnakes occurring in one location in Arizona and another in Mexico, but we have now shown that it's found in several places throughout the snake's distribution," Strickland explains. "There were also a few instances when individuals in our sample possessed both types of venom, which our data suggest are hybrids."

Breaking the rules

This preservation of multiple venom types within one species defies science's expectations. The principles of natural selection – "survival of the fittest" as it's often described – would predict that one of the venom types would fix and the other would slowly diminish over the course of several generations. The venom that wins out is dependent on which type – haemorrhagic or neurotoxic – best suits the Mojave rattlesnake as it hunts for prey in its arid desert habitat. Yet this is not what's happening.

The finding is made more peculiar by the results of a study in the summer of 2018 that revealed four genetically distinct lineages of the Mojave rattlesnake throughout the southwestern U.S. and central Mexico, along with evidence that the lineages are breeding with one another. Diving deeper into natural selection, this swapping of genes among Mojave rattlesnakes should have reduced the genetic diversity between their lineages, effectively standardising venom types until the fittest rules.

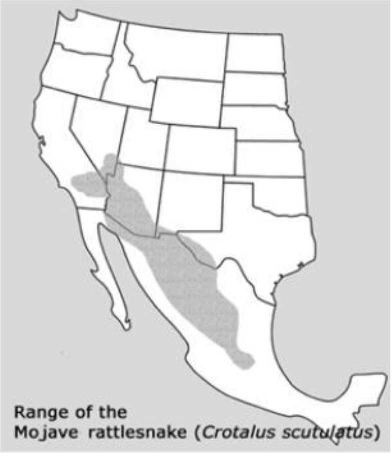
"From an evolutionary standpoint, this is abnormal. This is not what you'd expect," Strickland explains. "Gene flow should prevent this much variation. But even with the amount of gene flow that we find in these populations, the selection is strong enough to maintain these specific venom types in a very local environment."

"What we've been able to show is that there are local optima. In Texas, the neurotoxic venom type seems to be the optimum for this species. But if we go south into Mexico or over near Phoenix in Arizona, something in nature is changing, where the local optimum requires a different venom type," says Prof Parkinson, who holds a joint appointment at Clemson University in the College of Agriculture, Forestry and Life Science's forestry and environmental conservation department.

Public involvement in the investigation

The discovery required a large research collaboration between the principal investigators and students in five labs

Camping out in mojave rattlesnake country can be potentially dangerous - but it also provides the opportunity for helpers to get involved in studies, as in this case. Photo courtesy Dan Schreiber/www.shutterstock.com



The distribution of this species. Artwork courtesy Scutdude at en.wikipedia/PD.

across the USA and Mexico, in addition to almost 100 citizen scientists whom Strickland and colleagues assembled through social media and networking. In summary, the researchers helped to collect 216 Mojave rattlesnakes for their study in California, Arizona, New Mexico, Texas and Mexico. The herp community, it turns out, is a strong one, with everyday snake enthusiasts eager to help researchers for the betterment of the snake species.

The team met some of those herpers at an annual west Texas conference called SnakeDays, directed by enthusiast Jeff Adams. This event unites citizens who are interested in reptiles, as well as academics, fish and wildlife law enforcement and herp photographers, with the aims of celebrating and raising money for wildlife diversity conservation.

"By relying on the people at SnakeDays, what would have taken Jason and Chris some 10-20 years in time to study was then completed in just a few years," Adams explains. "It's much more efficient for scientific professionals to rely on citizens outside of their research boundaries, because citizens know more about finding the local flora and fauna. It's also cost-efficient. Citizen science reduces the cost of research projects so that researchers like Jason and Chris can better utilise their funding."

It's the citizen science aspect, as well as "the educational aspect of graduate students and postdocs working across borders," that Parkinson takes away from this study. "The science is really important - no question about that - but collaborative research and citizen science are so important to move science forward. It's not just about some geeky academic sitting in a room anymore, it's about how the research affects people," he says.

A venomous species with clinical importance

Less than 1 percent of the population in the USA is bitten by a venomous snake each year, and even fewer die from their symptoms. For the few unlucky people who are bitten, however, an understanding of the Mojave rattlesnake distribution can lead to better treatment outcomes. If doctors know what venom type persists in their region, they can administer the proper treatment more strategically.

"These authors have published the most extensive study of one of the most medically important snakes in North America, delivering provocative novel perspectives and surprising new discoveries," says Sean Bush, a clinical herpetologist at Eastern Carolina University. "This work provides an understanding of how and why venom varies, which translates clinically into a foundation for anti-venom development, drug choice and the tailored medical management of snakebites."

For scientists, the team's study points toward the Mojave rattlesnake as being a fascinating model species for population genetics and evolutionary studies. There are plenty of questions still to answer. Whether related to prey, the environment or a dietary shift over the course of development, why is the Mojave rattlesnake challenging science's predictions, for example? What is the mechanism? Future research in the Parkinson lab intends to consider these questions through studies of venom evolution in New World snake species, adhering to Strickland's guidelines for ethical animal research practices.

Mojave rattlesnake venom contains a number of harmful toxins that damage cells, neurons and tissues. Photo courtesy Gregory Territo.

The Mojave rattlesnake is a pit viper species living in the deserts of the southwest of the USA and Mexico. Photo courtesy Travis Fisher.

Further information

Jason L. Strickland, Cara F. Smith, Andrew J. Mason, Drew R. Schield, Miguel Borja, Gamaliel Castañeda-Gaytán, Carol L. Spencer, Lydia L. Smith, Ann Trápaga, Nassima M. Bouzid, Gustavo Campillo-García, Oscar A. Flores-Villela, Daniel Antonio-Rangel, Stephen P. Mackessy, Todd A. Castoe, Darin R. Rokyta, Christopher L. Parkinson. **Evidence for divergent patterns of local selection driving venom variation in Mojave Rattlesnakes *(Crotalus scutulatus)*.** *Scientific Reports*, 2018; 8 (1) DOI: 10.1038/s41598-018-35810-9

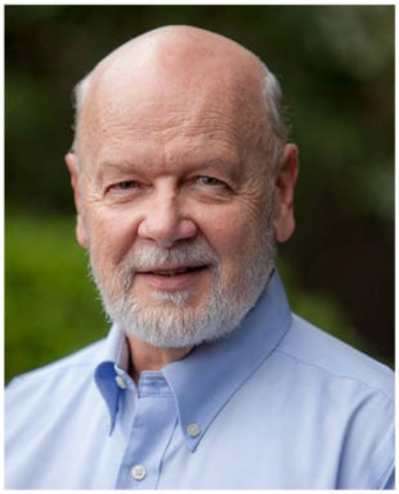
Compromising the cane toad's reproductive fertility

The cane toad (*Rhinella marina*) was deliberately introduced into Australia's sugar cane fields during 1935, in an attempt to control the native grey-backed cane beetle, which was a serious pest. Since then, however, this invasive species has spread across northern Australia where it has become a deadly threat to native predators, including monitor lizards and the northern quoll, leaving its march across the continent largely unchecked.

Understanding the dynamics of cane toad dispersal is therefore vital information for scientists working to help native animals survive the spread of this poisonous newcomer. Previous work into the reproduction of cane toads in northern Australia has documented low reproductive frequencies among females at the invasion front. Now we know, at least in part, why this is the case.

This photo of a cane toad was taken in a suburban part of Brisbane in Queensland, Australia, where the species has become well-established.

Photo courtesy Mr F/www.shutterstock.com



Professor Shine is working to combat the environmental impacts of the cane toad.

Photo courtesy Professor Shine/University of Sydney.

Professor Shine has previously instigated a training programme to deter native yellow-spotted monitors (*Varanus panoptes*) from eating cane toads which will otherwise kill these reptiles. Photo courtesy Matt Cornish/www.shutterstock.com

Spread matters more than sex

"It turns out that male cane toads are more interested in dispersal than sex at the invasion front," says Professor Rick Shine, an emeritus professor in the School of Life and Environmental Sciences, who also holds a position at Macquarie University. This means that over a relatively short period in evolutionary terms (about 85 years), the testes of male cane toads are much smaller at the edge of the species' territory than elsewhere.

In fact, toad testes on the invasion front are about 30 percent smaller than those of male toads in the core of the species' range, based on total body mass. "A pioneer cane toad, out at the edge of the invasion, is boldly going where no toad has gone before – and as a result, he isn't likely to meet many other toads out there," Professor Shine explains.

Gene matters

"So, when it comes time to breed, this pioneering cane toad will probably be the only male in the pond when a female comes along. Because his sperm won't have to compete with those of other males, he can afford to invest a bit less in making sperm, and a bit more into travelling faster and farther, to stay at the invasion front."

The evolutionary pressures in areas long-settled by the species mean that competition to breed is then much more intense. The study examined 241 adult males from three sites (one in the core region and two on the expansion front).

These toads are a definite handful.

Photo courtesy reptiles4all/www.shutterstock.com

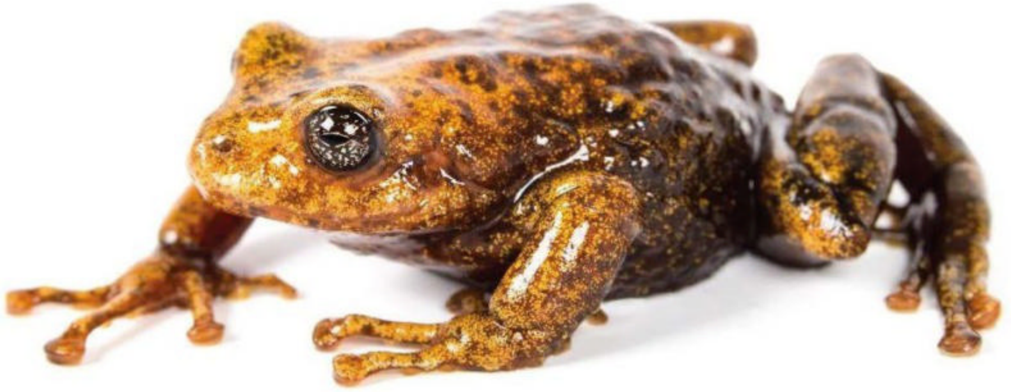
Professor Shine says: "For a male cane toad in a long-colonised area, competition with the others is intense and there's no benefit to extensive travel. So, a male in such a population produces a lot more sperm, to better win the sperm wars that erupt as a female lays her eggs. But this same competition does not apply on the boundaries of the expanding range of these toads, and so less sperm is utilised, with overall fertility levels being correspondingly lower as a consequence."

Further information

Christopher R. Friesen, Richard Shine. **At the invasion front, male cane toads (*Rhinella marina*) have smaller testes.** *Biology Letters*, 2019; 15 (7): 20190339 DOI: 10.1098/rsbl.2019.0339

Eleven new species of rain frogs discovered in Ecuador

Eleven previously-unknown species of rain frog have just been described by two scientists from the Museum of Zoology of the Pontifical Catholic University of Ecuador. Discovered in the Ecuadorian Andes, the species have been characterised in detail on the basis of their genetic, morphological (physical appearance) and ecological features as well as their calls. This is a particularly rare event, because of the number of new species that have been found at one time.

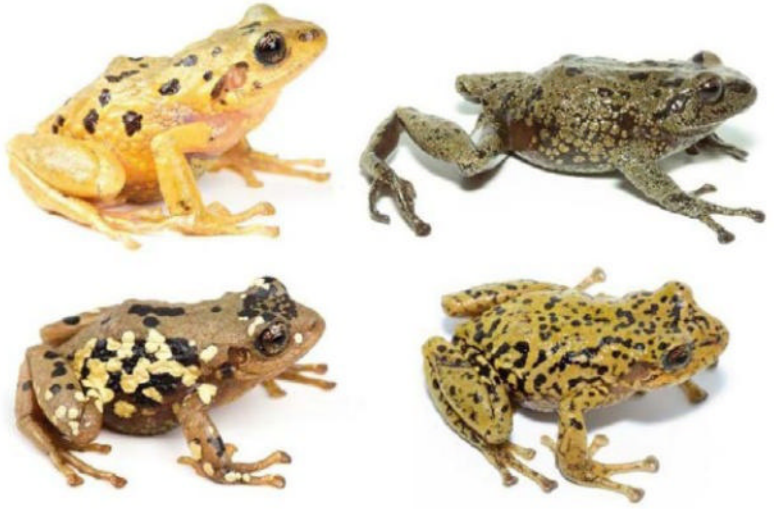


▲ **One of the newly-described species, now known to science *Pristimantis chomskyi*. Its name honours Noam Chomsky, a renowned linguist.** Photo courtesy David Velalcázar, BIOWEB-PUCE.

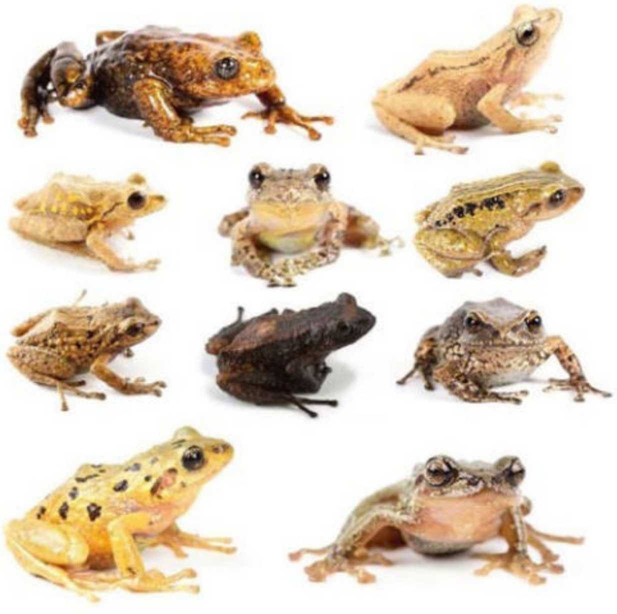
An amazing total

In the case of vertebrate animals generally, most scientific papers only list between one and five new species, because of the obvious difficulty in finding them and the huge amount of work involved in describing each one. Indeed, to put this Ecuadorian discovery into perspective, the last time that a similar number of undescribed frogs from the western hemisphere were reported was in 2007, when Spanish scientist Ignacio de la Riva described twelve species that he had found in Bolivia.

This new discovery by Nadia Paez and Dr Santiago Ron is astounding due to the fact that it comes as part of Nadia'a undergraduate thesis, when she was studying at the Pontifical Catholic University, where she was supervised by Professor Santiago Ron. Normally, such a publication would be the result of the efforts of a much larger team of senior scientists.



➤ **Variations of the multicolored rain frog. Its name makes reference to the outstandingly varied colouration within the species.** Photo courtesy BIOWEB-PUCE.



▲ **The rain frogs comprise a unique group of amphibians lacking a tadpole stage of development. Their eggs are laid on land and hatch as tiny froglets.** Photo courtesy BIOWEB-PUCE.

A worrying future

Unfortunately, amongst the findings of concern is that most of the newly described frog species are listed as either Data Deficient or Threatened with extinction, according to the criteria of the International Union for Conservation of Nature (IUCN). All of the studied amphibians appear to have very restricted geographic ranges, spanning less than 2,500 sq km (965 sq ml). To make matters worse, their habitats are being destroyed by human activities, especially cattle raising, agriculture and mining.

Amongst the newly-described species, there is the peculiar multicolored rain frog, where the name refers to its outstanding colour variations. Individuals can vary from bright yellow to dark brown. Initially, the studied specimens were assumed to belong to at least two separate species. However, genetic data demonstrated that they represented a single, even if highly variable, species.

The rest of the previously unknown frogs were either named after scientists who have made significant contributions in their fields, or given the names of the places where they were discovered, in order to highlight areas where conservation must be a priority.

Further reading

Paez NB, Ron SR (2019) **Systematics of Huicundomantis, a new subgenus of *Pristimantis* (Anura, Strabomantidae) with extraordinary cryptic diversity and eleven new species.** *ZooKeys* 868: 1-112. https://doi.org/10.3897/zookeys.868.26766.

Dragonfly interceptors

A green-eyed hawker (*Aeshna isoceles*) in flight.
Photo courtesy Mirko Graul/www.shutterstock.com

Be grateful you're not on a dragonfly's hunting list as a meal. You might be a fruit fly or maybe a mosquito, but it really wouldn't matter the moment you looked back and see four powerful wings pounding through the air after you. You fly for your life, weaving evasively, but the dragonfly somehow tracks you with seemingly instant reflexes. For a moment, you think you've got away, just as it closes in swiftly from below for the kill.

Then, as the dinosaur-era predator claws into you with its spiny legs and drags you into its jaws midair, you might wonder to yourself: "just how did it catch me with such a tiny brain and no depth perception?"

US-based Sandia National Laboratories is getting closer to the answer with their research showing how dragonfly brains might be wired to be extremely efficient at calculating complex trajectories. In recent computer simulations, artificial dragonflies in a simplified virtual environment successfully caught their prey using computer algorithms designed to mimic the way a dragonfly processes visual information while hunting. The positive test results confirmed that the programming is fundamentally a sound model.

The Sandia research is examining whether dragonfly-inspired computing could improve missile defence systems, which have the similar task of intercepting an object in flight, by making on-board computers smaller without sacrificing speed or accuracy. Dragonflies catch 95% of the prey that they target, making them one of the most efficient groups of predators in the world.

⌄ Sandia National Laboratories scientist Frances Chance, pictured here, is revealing insights into how dragonflies intercept their prey in flight might bizarrely be useful for designing missile defence systems.
Photo courtesy Randy Montoya.

Research replicates dragonfly's highly efficient brain

Frances Chance specialises in replicating biological neural networks — brains, basically — which require less energy and are better at learning and adapting than computers. Her studies focus on neurons, which are cells that send information through the nervous system.

"I try to predict how neurons are

wired in the brain and understand what kinds of computations those neurons are doing, based on what we know about the behaviour of the animal or what we know about the neural responses," she explains.

For example, a dragonfly's reaction time to a manoeuvering prey species is a mere 50 milliseconds. As a comparison, a human blink takes about 300 milliseconds. Fifty milliseconds is only enough time for information to cross about three neurons.

In other words, to keep up with a dragonfly, an artificial neural network needs to be constructed, capable of processing information after only three steps — but because brains fire lots of signals at once, each step may involve many calculations running at the same time.

▲ A dragonfly's eyes, as illustrated here by a *Zygoptera* dragonfly, can process information at a remarkably fast speed.
Photo courtesy ploypemuk/www.shutterstock.com

▼ A dragonfly with its prey. These insects are deadly hunters.
Photo courtesy Awei/www.shutterstock.com

A dragonfly's legs aid the agility of these insects, when both resting as here, and also in terms of seizing prey.
Photo courtesy boyphare/www.shutterstock.com

Faster, lighter computing for missile defence

Missile defence systems rely on established intercept techniques that effectively require a lot of computational steps. But rethinking those strategies using highly efficient dragonflies as a model could potentially bring a number of advances. These would include shrinking the size, weight and power needs of onboard computers, allowing interceptors to be smaller and lighter, and therefore more manoeuvrable.

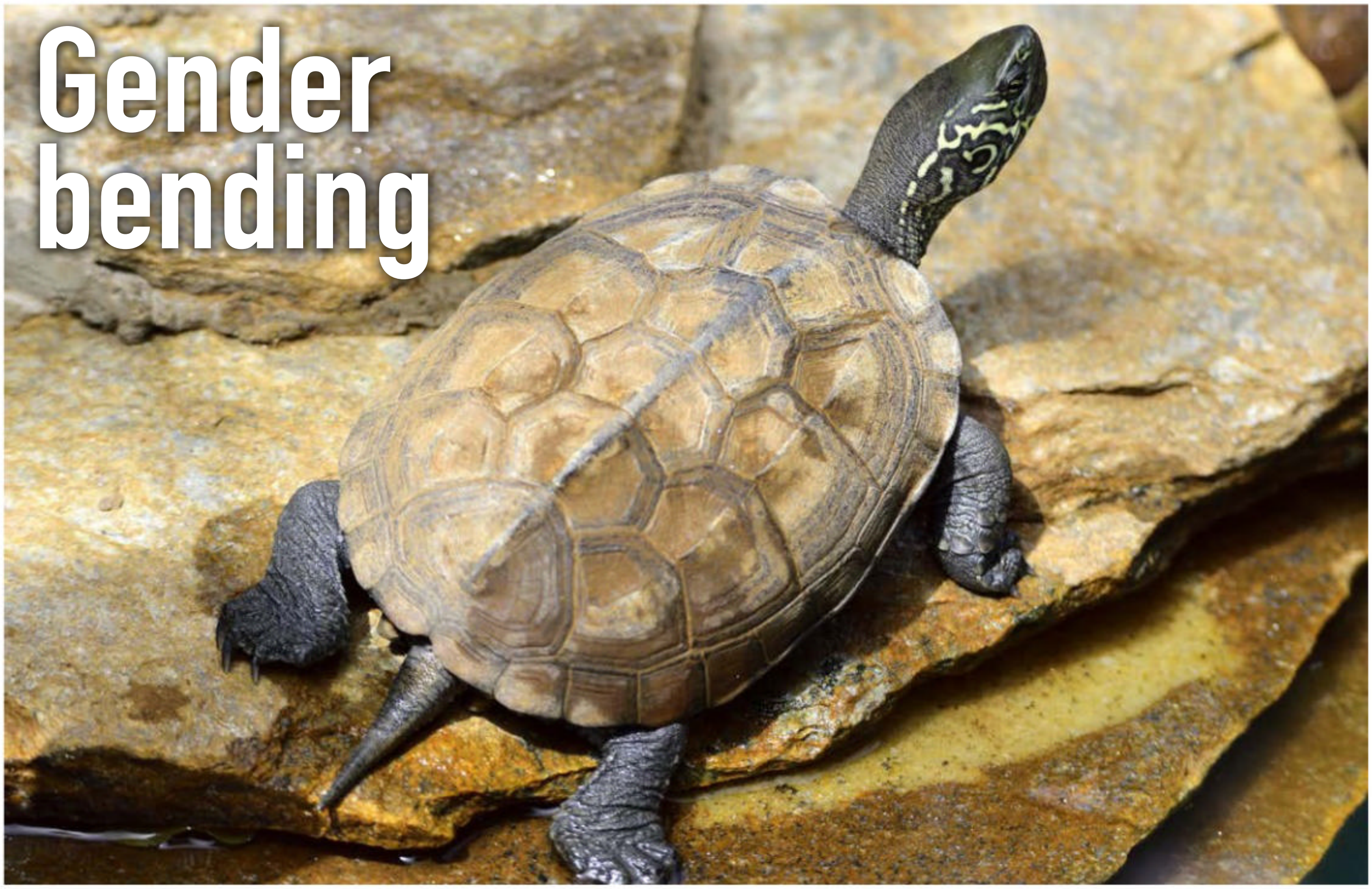
This research could also serve to reveal new ways to intercept manoeuvring targets such as hypersonic weapons, which follow less predictable trajectories than ballistic missiles. It could also provide new ways to home in on a target with less sophisticated sensors than are currently used.

Huge potential

Dragonflies and missiles move at vastly different speeds however, so it's unknown as to how well this research will ultimately translate to missile defence. But developing a computational model of a dragonfly brain could also could offer long-term benefits for machine learning and artificial intelligence (AI).

AI is now being used in many industries, ranging from self-driving transportation to prescription drug development. These fields stand to gain from highly efficient methods for constructing fast solutions to complex problems. Meanwhile, ongoing research at Sandia is refining Chance's algorithms and determining where they are most applicable.

Gender bending



▲ **Reeves's turtle was the subject of this study.**
Photo courtesy Luciano de la Rosa/www.shutterstock.com

Baby turtles influence their gender by moving around inside their eggs, new research has revealed. The idea that a reptile embryo can act in a way that affects its chances of developing as male or female has long been thought impossible, but findings by a team of scientists from China and Australia have now provided clear proof of the process.

This research therefore solves a long-standing evolutionary mystery and offers hope that at least some species regarded as being especially vulnerable to the effects of climate change will prove more robust than previously thought.

In order to carry out their study, the scientists, led by Wei-Guo Du from the Chinese Academy of Science in Beijing and including Macquarie University biologist Rick Shine, incubated several clutches of eggs laid in semi-natural nests by a freshwater species in the guise of Reeves's turtle *(Mauremys reevesii)*.

TSD and its restraints

Like those of many other reptiles, the eggs of this turtle are crucially dependent on the temperature of the nest, in terms of determining the gender of the offspring. It has long been known that incubation temperature influences gender in such species - a condition known as temperature-dependent sex determination (TSD). In fact, the prevalence of TSD has raised fears for the survival of many reptile species, as global warming becomes increasingly significant.

With temperatures continuing to rise, scientists suggest the usual 50-50 gender ratio will be heavily skewed, with the ultimate effect of reducing

▲ **It is now clear that local incubation conditions can have a big impact on the gender of the turtle hatchlings.**
Photo courtesy Sunset Paper/www.shutterstock.com

rates of reproduction to unsustainable levels. Yet not all the evidence, however, leads to the same conclusion - a fact that led Du, Shine and colleagues to investigate further.

"Reconstruction of the ancestral lineages of many TSD species shows that they have survived for millions of years," says Shine. "This includes periods when the average temperatures were much hotter than current climate change models predict."

Mother and offspring

Although maternal behaviours such as shifting the period of egg-laying to avoid the hottest times of the year and altering the nest structure might explain part of this survival mechanism, the adult turtles are powerless to protect their developing young from temperature changes once the eggs have been laid.

In order to find out whether turtle embryos were able to influence their own genders in any way, the researchers therefore manipulated conditions affecting the Reeves's turtle eggs that they were studying. They found that when these were warmed by a heat source set at an angle, each egg developed a significant thermal gradient, becoming warmer at one end. The embryos then moved inside the eggs in response. Those that shifted toward the warmer end developed into females, while those heading into the colder zone became male.

The researchers suspected that the embryos were detecting the temperatures through inbuilt bio-sensors called ion channels. To test this, they administered a drug which blocked ion activity, but did not otherwise affect the health of the animals. They found that the treated embryos did not move as far as untreated ones, and that sex ratios quickly became skewed. In cold conditions, almost all the turtles turned out male, with females dominating at higher temperatures.

Young in charge of their own destiny

"The discovery that embryos can influence their own development is truly remarkable," says Shine, adding that the findings constitute a rare conservation "good news" story for turtles.

"They are in desperate trouble all over the world - for example, they are eaten in Asia, and their habitats are being destroyed by short-sighted management of river systems in Australia," he explains. "It's encouraging to know that turtles may be better than we expected at dealing with some of the challenges wrought by climate change."

Young Reeves's turtles were able to influence their own gender while in the nest.
Photo courtesy Marek Velechovsky/www.shutterstock.com

For co-author Wei-Guo Du, the research provided a vindication of earlier work. A previous study by his team suggesting that movements by turtle embryos were triggered by temperature zones within eggs received a sceptical reception from some other scientists in the field. However, these new findings reinforce his initial conclusions.

A way to combat climate change?

"We previously demonstrated that reptile embryos could move around within their egg for thermoregulation, so we were curious about whether this could affect their sex determination too," he says. "We wanted to know if and how this behaviour could help buffer the impact of global warming on the sex ratios of offspring in these species."

Six of the seven scientists collaborating in the study are based in China - a fact, says Shine, that demonstrates the strength of the research community in that country. "Ecological and evolutionary research is flourishing in China, backed by substantial government investment and driven by a new generation of young Chinese scholars," he explains. "Increasingly, some of the best research about critical issues like climate change is coming from China."

Further information

Yin-Zi Ye, Liang Ma, Bao-Jun Sun, Teng Li, Yang Wang, Richard Shine, Wei-Guo Du. **The Embryos of Turtles Can Influence Their Own Sexual Destinies.** *Current Biology,* 2019; DOI: 10.1016/j.cub.2019.06.038

Moisture impacts on gender in turtles

Alarming results from a recent gender ratio study revealed that 99 percent of young green turtles *(Chelonia mydas)* from Australia's Northern Great Barrier Reef are female and that male sea turtles are disappearing. Now researchers from Florida Atlantic University (FAU) have documented a similar trend in sea turtle hatchlings within the US population, in southeast Florida. Since 2002, they have studied sea turtles in Palm Beach County and discovered that 97-100 percent of the hatchlings have been female.

In sea turtles, the sex of the offspring is determined by the nest's environment: warmer temperatures produce females and cooler temperatures produce males. However, it is not just temperature that affects the development process. Moisture changes the microclimate experienced by the eggs inside the nest, and this too can significantly affect their development. Wetter substrates tend to produce more males, while drier substrates lead to more female offspring.

The gender of sea turtles is being affected by rising global temperatures.
Photo courtesy blue-sea.cz/www.shutterstock.com

How humidity impacts

In a pioneering study, FAU researchers have managed to show why and how moisture conditions inside the nest affect the development and sex ratios of turtle embryos. They are the first to estimate sex ratios using a male-specific, transcriptional molecular marker known as Sox9, which acts as a marker of testis development in both sea turtles and freshwater turtles.

The moisture level in the substrate where the eggs are laid impacts on the gender of the offspring - it is now evident that it is not just the incubation temperature that is significant.
Photo courtesy Kalaeva/www.shutterstock.com

The researchers discovered that the coolest and the wettest substrates produced 100 percent male hatchlings, compared with 42 percent male offspring from the warmest and driest substrate. They also found that embryonic growth appears to be more sensitive to temperature at the earlier stages of development and to moisture later on.

"During incubation, the turtle embryo grows inside the nest from a few cells to a fully formed and independent organism at hatching," explains Dr Jeanette Wyneken, who is a professor of biological sciences in FAU's Charles E. Schmidt College of Science. "For proper development, embryos require an appropriate range of temperature, moisture, salinity, and respiratory gases."

Graduate students Jake Lasala (on the left) and Boris Tezak measure a sea turtle hatchling in Jeanette Wyneken's laboratory.
Photo courtesy Jay Paredes, Florida Atlantic University.

Using their novel experimental design, Wyneken and her colleagues discovered key differences in developmental rates, egg mass and sex ratios. Results show that embryos developed slowly in cooler and wetter sand substrates while water uptake by the eggs was significantly greater on wetter substrates.

"We found that developmental differences were due to moisture interacting with temperature where the increased water content of the sand resulted in temperatures that were 2-3°C (equivalent to 3.6-5.4°F) lower than air temperatures," she says.

Slider study

For the study, the researchers incubated eggs from red-eared sliders *(Trachemys scripta elegans),* a semi-aquatic freshwater turtle, under different temperature and moisture regimes to study the effect of the two environmental factors on developmental rate, egg mass, embryo mass and length, and sex ratio. They monitored embryonic development until the stage at which their sex is determined. Turtle embryonic development is divided into 27 stages and this takes place at stage 22.

The pivotal temperature is the constant temperature (29°C or 84.2°F) at which a 50:50 sex ratio is expected. The sex ratio was based on expression levels of Sox9 and all data obtained were carefully and checked.

The findings of this laboratory study are consistent with field studies with both freshwater turtles and sea turtles. Results of the study also are relevant when considering nesting factors in the wild, because conditions such as temperature and rainfall often vary across the nesting season.

"Our study demonstrates how moisture may change the incubation conditions inside nests by altering the temperature to which the eggs are exposed, which therefore affects development, growth and sex ratios," explains Wyneken.

"Furthermore, results of our study highlight the importance of including moisture conditions when predicting embryonic growth and sex ratios, and in developing models for embryonic development. Improving accuracy is particularly important when trying to assess the impact of climate change in species with temperature-dependent sex determination (TSD) and other forms of environmental determination."

Further information

Itzel Sifuentes-Romero, Boris M. Tezak, Sarah L. Milton, Jeanette Wyneken. **Hydric environmental effects on turtle development and sex ratio.** *Zoology,* 2017; DOI: 10.1016/j.zool.2017.11.009

It will be a number of years before the impacts of climate change today on the genders of young sea turtle become apparent in terms of breeding results. This is what makes it potentially so serious.
Photo courtesy SunflowerMomma/www.shutterstock.com

Red-eared slider hatchlings were used in the study.
Photo courtesy Prachaya Roekdeethaweesab/www.shutterstock.com

New study could reset how scientists view sex determination in painted turtle populations

▲ **Painted turtles occur over a very wide area of North America.** Photo courtesy Arnold John Labrentz/www.shutterstock.com

A new study from Iowa State University scientists could flip the established framework, in terms of how fellow researchers believe geography influences sex determination in painted turtles *(Chrysemys picta)*.

The study analysed decades of data concerning painted turtles, a species widely distributed across North America that undergoes temperature-dependent sex determination (TSD). That means the temperatures experienced by an incubating painted turtle egg influence whether an embryo develops the physical characteristics biologists describe as male or female. Warmer temperatures tend to produce females, and cooler temperatures yield males in this instance.

However, the study's findings defied theoretical expectations for how painted turtle populations respond to environmental variation, which could lead scientists to rethink how they look at the topic, according to Anna Carter, a postdoctoral research associate in ecology, evolution and organismal biology.

Latitude and temperature

Painted turtles cover a vast geographical range, extending from New Mexico north to Canada. That means populations experience wide variation in temperatures and environmental conditions across this area. For years, scientists have emphasised the "pivotal temperature," or the temperature that produces an equal number of males and females in a given population, when studying how the turtles respond to environmental variation. This framework would expect populations that live in warmer regions to have a higher pivotal temperature as well.

Carter explains that previous studies found patterns related to latitude. The closer a population was to the equator, then the higher its pivotal temperature. But using a massive dataset on painted turtle populations allowed the scientists to take an unprecedented look at the relationship between latitude and pivotal temperature, and the new analysis didn't find a convincing pattern.

New findings

Instead, the researchers found wide variation of as much as 5°C (9°F) in pivotal temperature within local populations. This discovery suggests temperature sensitivity of embryonic development can vary significantly from one turtle nest to another within a single population. "The implication of our study is that our understanding of local adaptation in this species isn't as good as we thought it was," Carter

admits. "Indeed, it might be useful to move away from pivotal temperature as a model."

The study, however, did find patterns connecting geography to the transitional range, or the range of temperatures that produce a mix of males and females. Transitional ranges tended to be wider at lower latitudes, Carter says.

The unexpectedly wide variation in pivotal temperature within populations could suggest painted turtles are more resilient to changes in temperature than previously thought. It's possible female painted turtles can nest successfully in a multitude of environments.

Massive historic dataset aids study

The study drew on a huge dataset collected over a span of decades by Fred Janzen, a professor of ecology, evolution and organismal biology, and his colleagues. Janzen explains that his lab has collected data on painted turtle populations on the Mississippi River near Clinton for 32 years. This data include both nesting and temperature measurements.

"I've been truly fortunate to meet folks willing to put in the time and effort to do this work," Janzen says. "It's a big ask. We're talking about year after year of each group putting together their own field crew to follow a turtle population."

For this study, the researchers modelled temperature-dependent sex determination (TSD) in 12 geographically distinct painted turtle populations, using both field data and lab incubation experiments.

⮝ **The factors influencing gender determination in painted turtle populations are more complex than previous thought.** Photo courtesy GTibbetts/www.shutterstock.com

⮝ **Temperatures vary from nest to nest, even in the same area.** Photo courtesy Elliotte Rusty Harold/www.shutterstock.com

⮝ **A nest of painted turtle eggs.** Photo courtesy Rejean Bedard/www.shutterstock.com

⮝ **A female painted turtle lays her eggs.** Photo courtesy Fredric Janzen.

Further information

Anna L. Carter, Brooke L. Bodensteiner, John B. Iverson, Carrie L. Milne–Zelman, Timothy S. Mitchell, Jeanine M. Refsnider, Daniel A. Warner, Fredric J. Janzen. **Breadth of the thermal response captures individual and geographic variation in temperature –dependent sex determination.** *Functional Ecology*, 2019; DOI: 10.1111/1365-2435.13410

Understanding scorpion venom

▲ **A scorpion with some wasabi.** Photo courtesy UCSF.

Researchers at University of California, San Francisco (UCSF) and Australia's University of Queensland have discovered a scorpion toxin that targets the "wasabi receptor," a chemical-sensing protein found in nerve cells that is responsible for the sinus-jolting sting of wasabi and also the flood of tears that can be associated with chopping onions.

Since the toxin triggers a pain response through a previously unknown mechanism, scientists think it can be used as a tool for studying chronic pain and inflammation, and may eventually lead to the development of new kinds of non-opioid pain relievers.

The scientists isolated the toxin, a short protein (known as a peptide) that they dubbed the "wasabi receptor toxin" (WaTx), from the venom of the black rock scorpion *(Urodacus manicatus),* whose range extends from Queensland through New South Wales and Victoria into South Australia.

▲ **Wasabi – also known as Japanese horseradish – is made from the roots of this plant, and is favoured in Japan as an accompaniment to sushi.** Photo courtesy sasaken/www.shutterstock.com

The discovery came as the researchers were conducting a systematic search for compounds in animal venom that could activate, and therefore be used to probe and study, the wasabi receptor – a sensory protein officially named TRPA1 (pronounced "trip A1") that is embedded in sensory nerve endings throughout the body. When activated, TRPA1 opens to reveal a channel that allows sodium and calcium ions to flow into the cell, which can induce pain and inflammation.

"Think of TRPA1 as the body's 'fire alarm' for chemical irritants in the environment," says John Lin King, a doctoral student in UCSF's Neuroscience Graduate Program. "When this receptor encounters a potentially harmful compound – specifically, a class of chemicals known as 'reactive electrophiles,' which can cause significant damage to cells – it is activated to let you know you're being exposed to something dangerous that you need to remove yourself from."

Used for defensive purposes

Cigarette smoke and environmental pollutants, for example, are rich in reactive electrophiles which can trigger TRPA1 in the cells that line the surface of the body's airway, potentially inducing coughing fits and a sustained inflammation of the airways. The receptor can also be activated by chemicals in pungent foods like wasabi, onions, mustard, ginger and garlic – compounds that, according to Lin King, may have evolved to discourage animals from eating these plants. WaTx appears to have evolved for the same reason.

Though many animals use venom to paralyse or kill their prey, WaTx seems to serve a purely defensive purpose. Virtually all animals, from worms to humans, have some form of TRPA1. But the researchers found that WaTx can only activate the version found in mammals, which aren't on the menu for black rock scorpions, suggesting that the toxin is used essentially to ward off mammalian predators therefore.

"Our results provide a beautiful and striking example of convergent evolution, whereby distantly related life forms – plants and animals – have developed defensive strategies that target the same mammalian receptor through completely distinct strategies," explains David Julius, professor and chair of UCSF's Department of Physiology. But what the researchers found most interesting about WaTx was its mode of action. Though it triggers TRPA1, just as the compounds found in pungent plants do – and even targets the very same site on that receptor – the way it activates the receptor was novel and unexpected.

Gaining access

First, WaTx forces its way into the cell, circumventing the standard routes that place strict limits on what's allowed in and out of cells. Most compounds, from tiny ions to large molecules, are either ingested by the cell through a complex process known as "endocytosis," or they gain entry by passing through one of the many protein channels that stud the cell's surface and act as gatekeepers.

But WaTx contains an unusual sequence of amino acids that allows it

▲ **A black rock scorpion - seen here fluorescing under ultraviolet (UV) light, which is an unusual characteristic of this group of arachnids.** Photo courtesy Patrick Cooper/www.shutterstock.com

simply to penetrate the cell's membrane and pass right through to the cell's interior. Few other proteins are capable of the same feat. The most famous example is an HIV protein called Tat, but surprisingly, WaTx contains no sequences similar to those found in Tat or in any other protein that can pass through the cell's membrane.

"It was surprising to find a toxin that can pass directly through membranes. This is unusual for peptide toxins," Lin King said. "But it's also exciting because if you understand how these peptides get across the membrane, you might be able to use them to carry things – drugs, for example – into the cell that can't normally get across membranes."

Once inside the cell, WaTx attaches itself to a site on TRPA1 known as the "allosteric nexus," the very same site targeted by pungent plant compounds and environmental irritants like smoke. But that's where the similarities end.

Plant and environmental irritants alter the chemistry of the so-called 'allosteric nexus', which causes the TRPA1 channel to rapidly flutter open and closed. This allows positively charged sodium and calcium ions to flow into the cell, triggering pain. Though both ions are able to enter when TRPA1 is activated by these irritants, the channel exhibits a strong preference for calcium and lets much more of it into the cell, which leads to inflammation.

By contrast, WaTx wedges itself into the allosteric nexus and props the channel open. This abolishes its preference for calcium. As a result, overall ion levels are high enough to trigger a pain response, but calcium levels remain too low to initiate inflammation.

To demonstrate this, the researchers injected either mustard oil, a plant irritant known to activate the wasabi receptor, or WaTx into the paws of mice. With mustard oil, they observed acute pain, hypersensitivity to temperature and touch – key hallmarks of chronic pain – and inflammation, as evidenced by significant swelling. But with WaTx, they observed acute pain and pain hypersensitivities, but no swelling.

Hope for the development of new painkillers

"When triggered by calcium, nerve cells can release pro-inflammatory signals that tell the immune system that something's wrong and needs to be repaired," Lin King explains. "This 'neurogenic inflammation' is one of the key processes that becomes dysregulated in chronic pain. Our results suggest that you can decouple the protective acute pain response from the inflammation that establishes chronic pain. Achieving this goal, if only in principle, has been a longstanding aim in addressing pain."

The researchers believe their findings will lead to a better understanding of acute pain, as well as shedding more light on the link between chronic pain and inflammation, which were previously thought to be experimentally indistinguishable. The findings may even lay the groundwork for the development of new pain drugs.

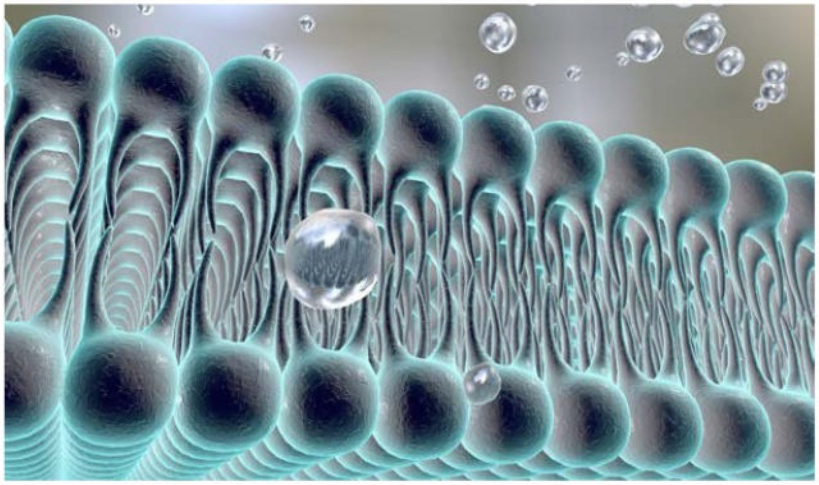
"The discovery of this toxin provides scientists with a new tool that can be used to probe the molecular mechanisms of pain, in particular, to selectively probe the processes that lead to pain hypersensitivity," Lin King adds. "And for those interested in drug discoveries, our findings underscore the promise of TRPA1 as a target for new classes of non-opioid analgesics to treat chronic pain."

▲ **David Julius, PhD, senior author of the new study.**

Photo courtesy UCSF.

▼ **It is possible this research could create a brand new form of pain-killer, all thanks to a scorpion!**

Photo courtesy wutzkohphoto/www.shutterstock.com



◀ **Cell membranes have specific channels running into them, through which some molecules can pass.**

Illustration courtesy Kateryna Kon/www.shutterstock.com

Further information

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How storms are shaping spider development

Researchers from McMaster University in Ontario, Canada, who rush in after storms to study the behaviour of spiders, have found that extreme weather events such as tropical cyclones may have an evolutionary impact on populations living in storm-prone regions, where aggressive spiders have the best odds of survival. Raging winds can demolish trees, defoliate entire canopies and scatter debris across forest floors, radically altering the habitats and reshaping the selective pressures on many organisms, according to the team's findings.

"It is tremendously important to understand the environmental impacts of these extreme weather events on evolution and natural selection," explains Jonathan Pruitt, an evolutionary biologist and Canada 150 Chair in McMaster's Department of Psychology, Neuroscience & Behaviour. "As sea levels rise, the incidence of tropical storms will only increase. Now more than ever, we need to contend with what the ecological and evolutionary impacts of these storms will be for animals, quite apart from ourselves."

Moving quickly

Pruitt and his team examined female colonies of the species known as the social cobweb spider *(Anelosimus studiosus)*, which lives along the Gulf and Atlantic coasts of the United States and Mexico, directly in the path of tropical cyclones that form in the Atlantic basin from May to November each year.

In order to conduct the research, scientists had to tackle many logistical and methodological challenges which included anticipating the trajectory of the tropical cyclones. Once a storm's path was determined, they sampled populations before landfall, then returned to the sites within 48 hours.

The researchers sampled 240 colonies throughout the storm-prone coastal regions, and compared them to control sites, with particular interest in determining if extreme weather—in this case, areas disturbed in 2018 by subtropical storm Alberto, Hurricane Florence and Hurricane Michael—caused particular spider traits to prevail over others.

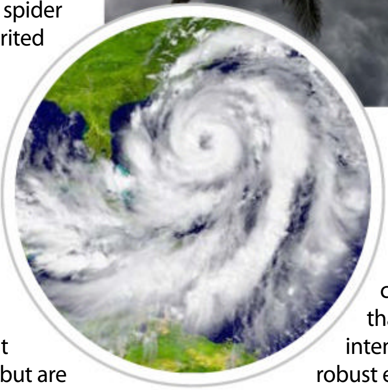
As a species, the social cobweb spider is divided into two groups of inherited personality traits: docile and aggressive. The aggressiveness of a colony is determined by the speed and number of attackers that respond to prey, the tendency to cannibalise males and eggs, plus vulnerability to infiltration by predatory foreign spiders among other characteristics. Aggressive colonies, for example, are better at acquiring resources when scarce, but are also more prone to infighting when deprived of food for long periods of time or when colonies become overheated.

Aggression pays dividends

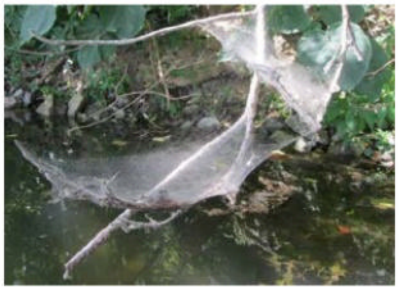
"Tropical cyclones likely impact both of these stressors by altering the numbers of flying prey and increasing sun exposure from a more open canopy layer," explains Pruitt. "Aggressiveness is passed down through generations in these colonies, from parent to daughter, and is a major factor in their survival and ability to reproduce."

The analysis suggested that after a tropical cyclone event, colonies with more aggressive foraging responses produced more egg cases and had more spiderlings that survived into early winter. The trend was consistent across multiple storms that varied in size, duration and intensity, suggesting the effects are robust evolutionary responses. This research also forms part of a much larger project examining the impact of tropical cyclones on hundreds of species in the ecosystem.

Jeff Gammons StormVisuals/www.shutterstock.com

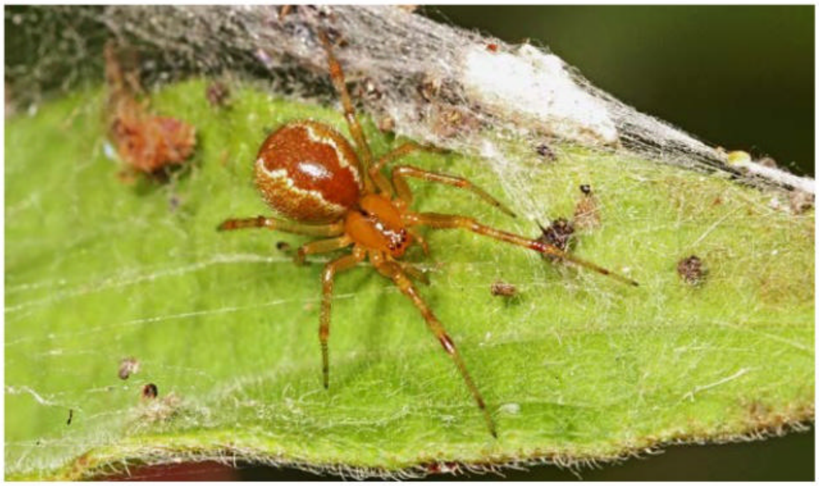


⮝ A severe tropical cyclone blowing in over the US coast. Photo courtesy Harvepino/NASA/www.shutterstock.com



⮝ A colony of the spiders.
Photo courtesy Jonathan Pruitt.

➤ These small spiders are becoming more aggressive in some areas, with this aggression likely to be linked to climate change.
Photo courtesy Joseph T. Lapp.



◄ Social cobweb spider - *Anelosimus studiosus*, Loxahatchee National Wildlife Refuge, Boynton Beach, Florida. Photo courtesy Judy Gallagher cc-by-2.0

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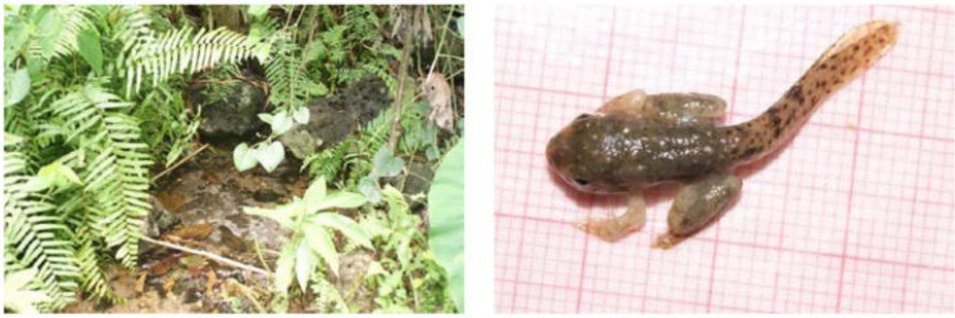
Alexander G. Little, David N. Fisher, Thomas W. Schoener, Jonathan N. Pruitt. **Population differences in aggression are shaped by tropical cyclone-induced selection.** *Nature Ecology & Evolution*, 2019; DOI: 10.1038/s41559-019-0951-x

Giant frogs build ponds for their young

The first example of nursery-building in an African amphibian - the goliath frog *(Conraua goliath)*, - has been reported and could serve to explain just why these anurans have grown to be giant in size. Researchers observed adult goliath frogs in the wild and found that they move rocks weighing up to 2kg (4.4lb) while building ponds for their young, which they then guard. Goliath frogs themselves weigh up to 3.3kg (7.3lb) and their bodies reach over 34cm (13in), without including their legs, and are therefore the largest frogs in the world.

"Goliath frogs are not only huge, but our discovery shows they seem to be attentive parents as well," says author Marvin Schäfer from the Berlin Natural History Museum. "The little ponds they make at the edges of fast-flowing rivers provide their eggs and tadpoles with a safe haven from sometimes torrential waters, as well as from the many predators living there. We think that the heavy work they put into excavation and moving rocks may explain why gigantism evolved in these frogs in the first place."

An adult goliath frog. Photo courtesy Dr Mark-Oliver Rödel/Taylor & Francis.


Recently metamorphosed juvenile frogs are often found in vegetation near nesting sites, indicating they stay around their nursery pool for some time. Photo courtesy Dr Mark-Oliver Rödel/Taylor & Francis.

A little-studied species

Goliath frogs are found only in Cameroon and Equatorial Guinea, and little is known about their biology, particularly their reproductive behaviour. The numbers of this endangered species have declined by more than 50 per cent in just 10 years, due to overhunting and deforestation; and researchers first learned about the unusual level of parental care they provide from local frog hunters, who trap adults for bush meat.

Subsequently, in order to investigate the behaviour, two researchers waded along opposite edges of the Mpoula River in western Cameroon looking for breeding sites. At first, they could only distinguish them by finding eggs or tadpoles. However, they soon learned to spot material excavated and piled up in a way that defied the effects of the water current.

They identified 22 potential breeding sites, 14 of which contained nearly 3,000 eggs each, spread across the entire area. At the nest which showed the most recent signs of activity, they recorded a time-lapse video using a camera trap.

Goliath froglets are less than 18mm (0.7in) when they leave the relatively safety of their nursery pool. Photo courtesy Dr Mark-Oliver Rödel/Taylor & Francis.

Different types of pond created

The scientists found that goliath frogs create three different types of pond. For some, they simply clear naturally-occurring rock-pools of leaf-litter and debris. The effect is still strikingly different to surrounding puddles, which have thick layers of leaves, debris and gravel. In the second case, frogs dig out leaf litter and gravel from shallow pools and push it to the edges, forming a dam.

Dams are most obvious in the third type of construction though, for which frogs clear depressions of shallow water of any large stones, moving them to the edge and creating circular ponds. This was the most reliable type, as eggs were least likely to spill out if the area became flooded after heavy rain.

Another example of parental care

Infrared time-lapse revealed an adult spending all night guarding a nest from predators, only ending the vigil just before dawn. The scientists were unable to determine which sex was responsible for building ponds or which for guarding them, although one hunter who described the behaviours in detail suggested that males do the construction while females are the guards. They didn't directly observe the cleaning or digging process, but followed the progress of a nest over the course of five days, from the first digging attempts through to the deposition of eggs.

Dr Mark-Oliver Rödel, project leader and president of Frogs & Friends, says: "The fact that we've only just discovered these behaviours shows how little we know about even some of the most spectacular creatures on our planet. We hope that our findings, combined with further ongoing research, will improve our understanding of the needs of the goliath frog so we can help support its continued survival."

Further information

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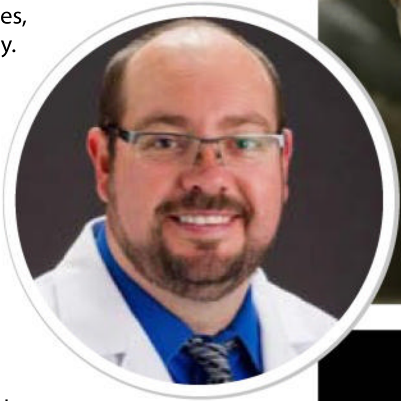
Teeth cleaning not on the menu

Unlike people, crocodiles do not clean their teeth to slow down wear and tear. Instead, they simply lose them and replace them with new copies. Having one of the most powerful bites in the animal kingdom, crocodiles must be able to bite hard in order to catch and eat their food, which includes turtles, wildebeest and other large prey.

Now, researchers at the University of Missouri have found that crocodiles — and even their plant-eating ancestors — had thin tooth enamel, a trait that is in stark contrast to humans and other hard-biting species. These findings could suggest new approaches for dealing with some of our dental problems.

"Once we unlock genetically how crocodiles and other non-mammals do this, maybe new teeth can be bioengineered for people," says researcher Brianne Schmiegelow. "Instead of using fillers such as crowns, people could instead 'grow' new teeth when they need to replace those that have become worn or decayed."

➤ **Crocodiles replace their teeth through their lives.** Photo courtesy Zoltan Tarlacz/ www.shutterstock.com



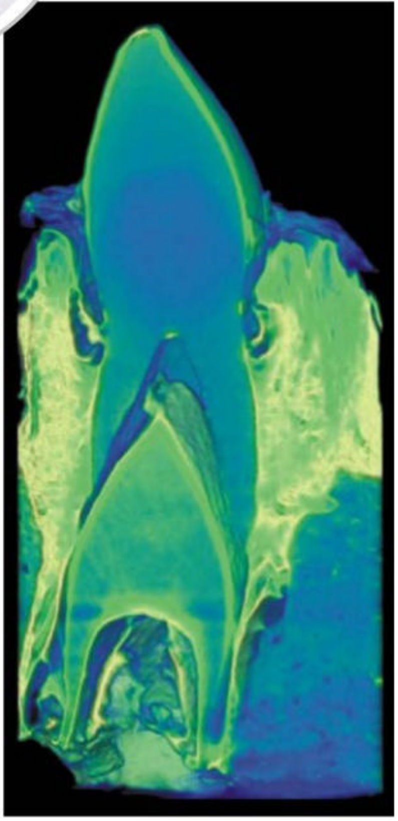
⮝ **Casey Holliday, an associate professor of anatomy in the MU School of Medicine,** Photo courtesy University of Missouri.

Scanning gives clear insights

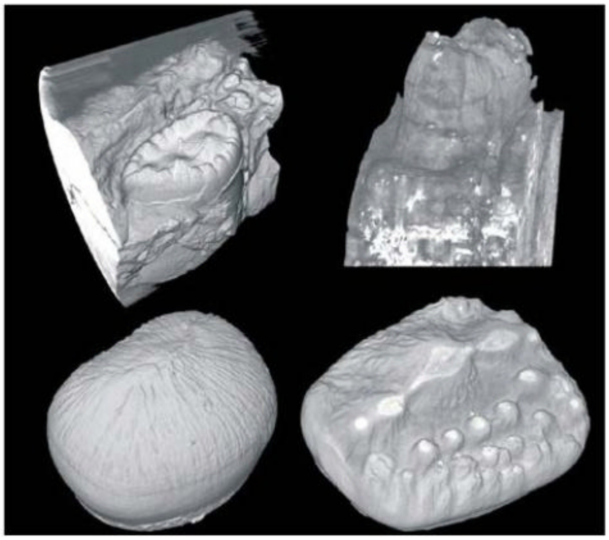
The team used a three-dimensional X-ray scanner to measure the thickness of tooth enamel in crocodiles. They found regardless of tooth position — incisor, canine, molar — age or diet, crocodiles do not have thick tooth enamel.

With this new information, the team also studied published data on dinosaur teeth and found that the data nearly matched what they were seeing in crocodiles. For instance, a *Tyrannosaurus rex* had the same enamel thickness as a crocodile and yet could also bite extremely hard.

"Crocodiles bite really determinedly, so we were curious if they have teeth that will correspondingly withstand those forces — tough teeth to match a tough bite," explains Kaleb Sellers, from the School of Medicine at the University of Missouri. "We found that they don't have tough teeth, and we think it's because they replace their teeth like most other non-mammal animals. That made us wonder if other animals — even prehistoric — had similar issues."



➤ **The team used a three-dimensional x-ray scanner to measure the thickness of tooth enamel in crocodiles. An alligator tooth is shown here.** Photo courtesy University of Missouri.



⮝ **Examples of fossilised crocodile teeth. Even plant-eating crocodiles replaced their teeth regularly.** Photo courtesy University of Missouri.

More questions arise

The team say the next step is to study tooth replacement and the timing of tooth growth in crocodiles and other animals such as dinosaurs — even looking into the possibility of genetic causes. "Enamel takes a long time to build, so it's not something animals will do 'off-the-cuff,' so to speak," explains Casey Holliday, an associate professor of anatomy in the MU School of Medicine.

"It presents us with an interesting puzzle. If ancient crocodiles were chewing plants, did their new teeth already have the correct architecture — in terms of dimples and facets — to allow for this chewing? The findings here have paved the way for exploring this mystery with future research."

Further reading

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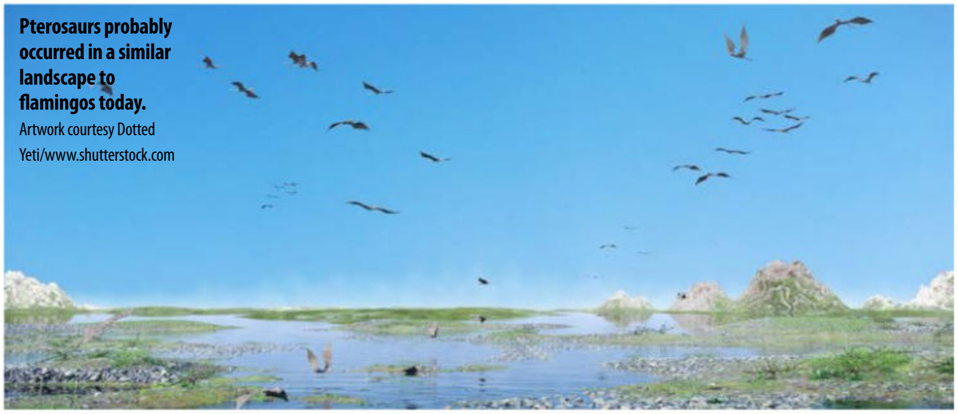
Filter-feeding pterosaurs were the flamingos of the Late Jurassic



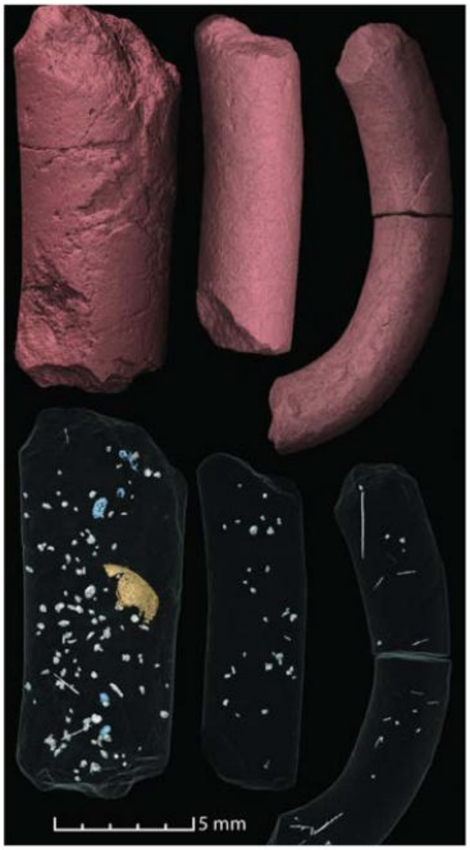
Pterosaurs probably occurred in a similar landscape to flamingos today. Artwork courtesy Dotted Yeti/www.shutterstock.com

Modern flamingos employ a filter feeding technique and their faeces are, as a result, rich in remains of microscopically-small aquatic prey. Very similar findings have now been described in pterosaur droppings dating back more than 150 million years. This discovery represents the first direct evidence of filter-feeding in Late Jurassic pterosaurs, and demonstrates that their diet and feeding environment were similar to those of modern flamingos.

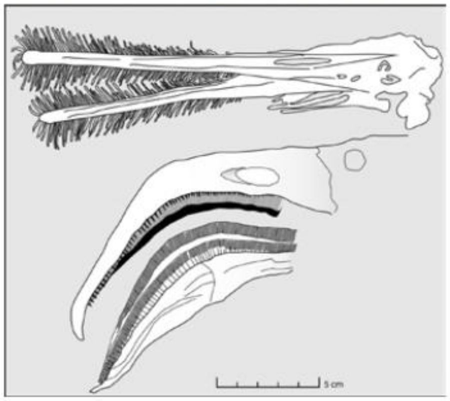
Pterosaurs were a diverse group of flying reptiles that roamed the skies during the age of dinosaurs. Skeletal fossils suggest that they, just like modern birds, adapted to diverse lifestyles and feeding habits. Direct evidence on diets such as gut contents, however, are rare and only known from a few pterosaur species.

Coprolites, which are fossilised droppings, are surprisingly common though and they potentially hold valuable information on the diet of extinct animals. Unfortunately, however, it is often difficult to know which animal produced which dropping.

In a recent paper, researchers from Uppsala University and the Polish Academy of Sciences describe the contents of three coprolites collected from an area with abundant pterosaur footprints, within the Wierzbica Quarry in Poland. The coprolites' size, shape and association to the tracks suggest that they were produced by pterosaurs, most probably belonging to a group called Ctenochasmatidae.



⮝ The fossil droppings were scanned by synchrotron microtomography, which made it possible to image the contents of fossils in a 3D format. Photo courtesy Qvarnström mfl.



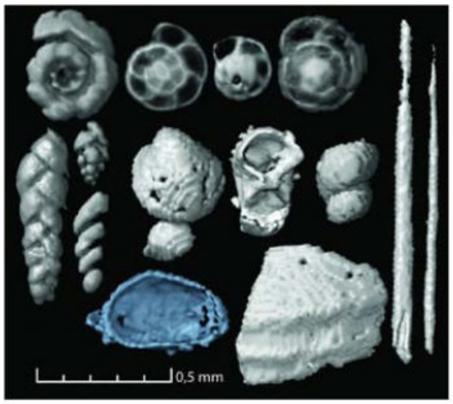
⮝ Some Late Jurassic ctenochasmatids had elongated snouts with many slender teeth, which have been interpreted as adaptations for filter feeding. These are shaped similarly to those of modern-day flamingos, providing an example of what scientists often term 'convergent evolution'. Illustration courtesy Qvarnström et al.

Scanning provides lifestyle insights

The fossil droppings were scanned using a technique known as synchrotron microtomography. This works in a similar way to a CT-scanner in a hospital but has much stronger X-ray beams, making it possible to image the contents of fossils in three dimensions. The scans revealed many microscopic food remains including foraminifera (small amoeboid protists with external shells), small shells of marine invertebrates and the possible remains of polychaete worms.

"A reasonable explanation for how a pterosaur big enough to have produced the droppings ingested such small prey is through filter feeding," says Martin Qvarnström, who is based at Uppsala University.

Some ctenochasmid pterosaurs are thought to have been filter feeders. The pterosaur *Pterodaustro,* which comes from the Cretaceous and is thus slightly younger than the Polish coprolites, possessed a sieving basket consisting of many long, thin teeth and was certainly a filter feeder. Older ctenochasmids did not possess such an obvious sieving basket, but some had elongated snouts with many slender teeth, also interpreted as adaptations for filter feeding.



⮝ Images of the food remains of the pterosaurs, discovered in their fossilised droppings. Photo courtesy Qvarnström mfl.

These pterosaurs were around at the time the droppings were deposited, and as the footprints from the site have also been attributed to ctenochasmids, it is therefore likely that such pterosaurs produced both the droppings and the footprints.

"The similar contents of the droppings of flamingos and the pterosaur coprolites could be explained by similar feeding environments and mesh sizes of the filter-feeding apparatus. It appears therefore that the pterosaurs which produced the footprints and droppings found in Poland were indeed the flamingos of the Late Jurassic," adds Martin Qvarnström.

Further information

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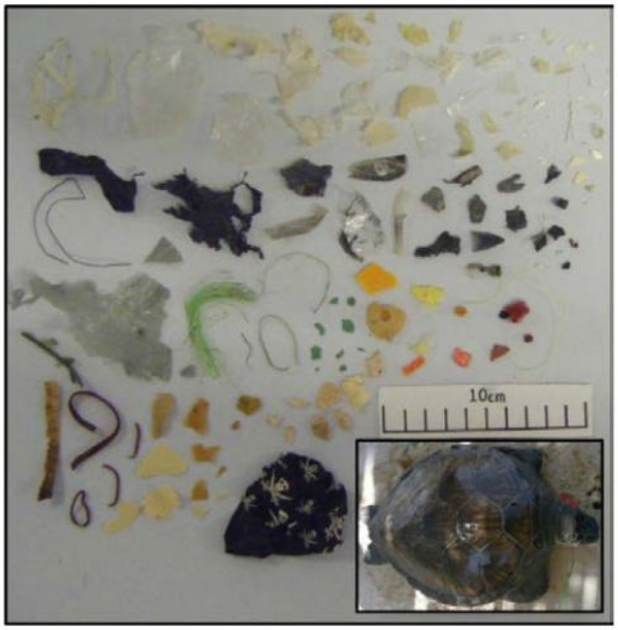
Green turtles eat plastic that looks like their food

These turtles are drawn to certain types of plastic, such as green straws, possibly because their appearance mimics that of their natural food. Photo courtesy Rich Carey/www.shutterstock.com

Green turtles *(Chelonia mydas)* are more likely to swallow plastic that resembles their natural diet of sea grass, according to new research. The study found that turtles strongly favour narrow lengths of plastic in natural colours like green and black, rather than debris of other shapes and colours.

Scientists from the University of Exeter and the Society for the Protection of Turtles (Cyprus) examined the guts of turtles found washed up on beaches in Cyprus. Plastic debris was found in all turtles whose full gastrointestinal tract could be examined, with the number of pieces ranging from three to no less than 183 pieces.The study could not determine what, if any, role the plastic had in the turtles' deaths however. Most had likely died as a result of interaction with fishing nets.

⮟ Some of the plastic found in green turtles, set against a 10cm (4in) scale. Photo courtesy University of Exeter.



"Previous research has suggested leatherback turtles eat plastic that resembles their jellyfish prey, and we wanted to know whether a similar thing might be happening with green turtles," explains Dr Emily Duncan, of the University of Exeter. "Sea turtles are primarily visual predators - able to choose foods by size and shape - and in this study, we found strong evidence that green turtles favour plastic of certain sizes, shapes and colours.

Differences emerge

"Compared to a baseline of plastic debris on beaches, the plastic we found in these turtles suggests they favour threads and sheets that are black, clear or green. The sources of this plastic might include things like black bin bags, and fragments from items such as fishing rope and carrier bags."

The study found smaller turtles tended to contain more plastic, possibly because they are less experienced (and therefore more likely to eat the wrong food) or because dietary choices change with age and size. Of the 34 turtles examined, the scientists were able to examine the full gastrointestinal tracts of 19 of this total.

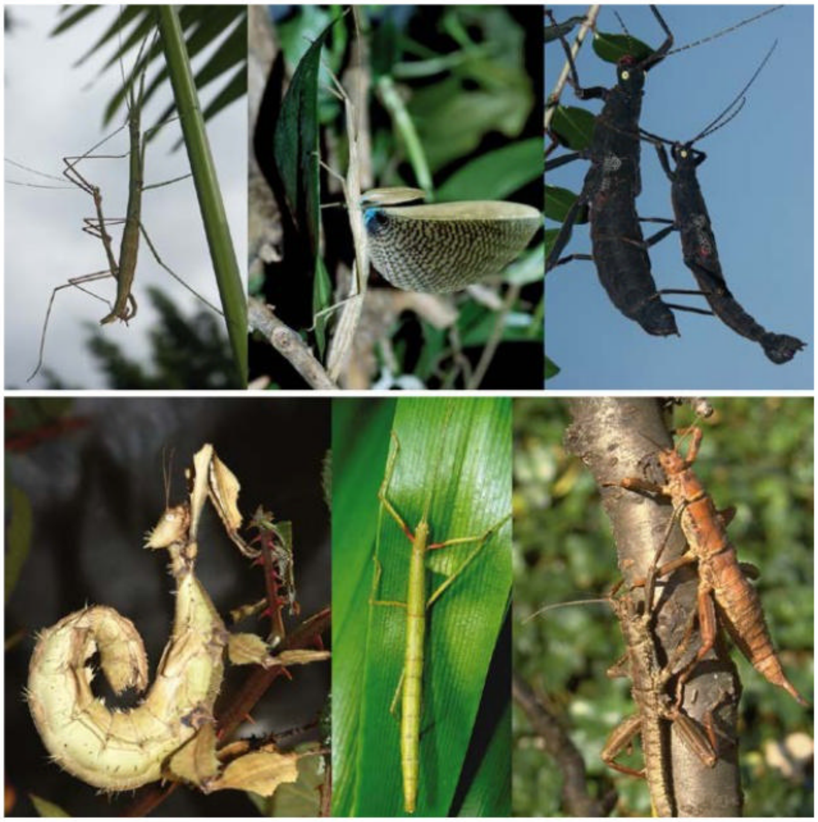
"Research like this helps us understand what sea turtles are eating, and whether certain kinds of plastic are being ingested more than others," says Professor Brendan Godley, who leads the Exeter Marine research strategy. "It's important to know what kinds of plastic might be a particular problem, as well as highlighting issues that can help motivate people to continue to work on reducing overall plastic consumption and pollution."

Further information

Emily M. Duncan, Jessica A. Arrowsmith, Charlotte E. Bain, Hannah Bowdery, Annette C. Broderick, Tierney Chalmers, Wayne J. Fuller, Tamara S. Galloway, Jonathon H. Lee, Penelope K. Lindeque, Lucy C. M. Omeyer, Robin T. E. Snape, Brendan J. Godley. **Diet-related selectivity of macroplastic ingestion in green turtles *(Chelonia mydas)* in the eastern Mediterranean.** *Scientific Reports,* 2019; 9 (1) DOI: 10.1038/s41598-019-48086-4

What shaped stick insects?

Stick and leaf insects are a diverse and strikingly bizarre group of insects with a world-wide distribution, although they are more common in tropical and subtropical areas. They are famous for their impressively large body size, compared with other insects, and of course, their remarkable ability to camouflage themselves as twigs, leaves or bark in order to hide from potential predators. A team of international researchers led by the University of Göttingen has now generated the first phylogenomic tree of these insects, revealing their relationships, and has come up with some interesting findings.



➤ Stick insect relatives: different in appearance but of the same origin. Surprisingly, New World (above) and Old World stick insects (below) form their own evolutionary lines within this insect group, as this new study confirms. From top left to bottom right: a pair of Mexican stick insects (*Pseudosermyle phalangiphora*), female *Metriophasma diocles* from Panama, pair of black velvet stick insects (*Peruphasma schultei*) from Peru, a female Australian giant prickly stick insect (*Extatosoma tiaratum*), a female Indian stick insect (*Carausius morosus*), and a pair of "tree lobster" stick insects (*Eurycantha calcarata*) from New Guinea.

Photo courtesy Christoph Seiler.

Detailed insight

"Previously the relationships between stick insects were simply inferred, being based on just a handful of genes. This is the first study in which more than 2,000 genes were analysed for each species," explains Dr Sven Bradler from the University of Göttingen.

Some 38 species of stick and leaf insects from all over the world were investigated by the researchers from the 1KITE project (an abbreviation for 1,000 Insect Transcriptome Evolution). "Previous studies were unable to explain the early evolution of these insects. This has now changed with the new and much more extensive dataset which allows us even to reconstruct the origin of the oldest lineages," adds fellow researcher Dr Sabrina Simon, from the University Wageningen.

⮟ This new research indicates that all of Madagascar's colourful stick insects are descended from a common ancestor. This is *Achrioptera maroloko*, one of two species recently discovered there by Drs Graw, Sven Bradler and colleagues. 'Maroloko' means 'colourful' in the native Malagasy language.

Photo courtesy Dr. Frank Glaw.

Surprising findings

The most surprising finding is that the relationships between the early emerging groups of stick and leaf insects largely disprove the earlier assumptions. In fact, the genealogy reflects more the geographic distribution than the anatomical similarity of the animals. The research revealed a New World lineage of purely North and South American species, and a group of Old World origin that comprises species from Africa to New Zealand.

The biogeographic history was reconstructed by Sarah Bank, a PhD student at the University of Göttingen and this aspect of the study also highlighted further unexpected results: "The flamboyant stick insects of Madagascar, for instance, are descended from a single ancestral species which colonised the island approximately 45 million years ago," she explains.

What shaped their appearance?

The age estimation of the phylogenetic tree suggests that most of the old lineages emerged after the dinosaurs became extinct 66 million years ago. Thus, the remarkable camouflage of stick and leaf insects most probably evolved subsequently, as adaptation against predatory mammals and birds.

"Stick insects are becoming more and more important as model organisms for evolutionary research. The new comprehensive molecular dataset won't be exhaustively analysed for quite some time and it will provide exciting insights to guide further genetic research," adds Dr Bradler.

⮝ Dr Sven Bradler. Photo courtesy University of Göttingen.

Further information

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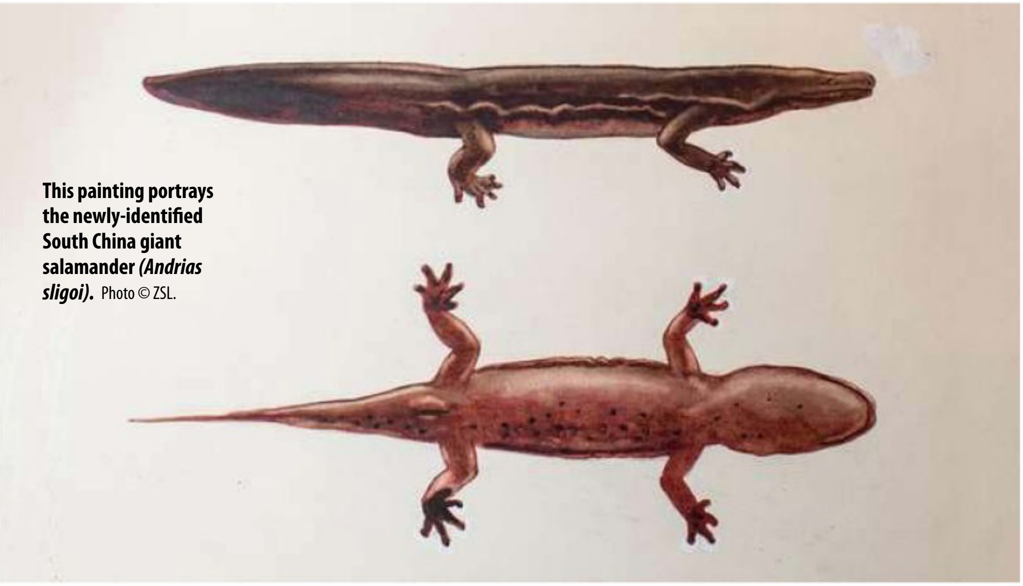
Newly-discovered amphibian species believed to be the largest alive today

Using DNA from museum specimens collected in the early 20th century, scientists from ZSL London Zoo and London's Natural History Museum have just identified two previously-unrecognised species of giant salamander - one of which they suspect is now the world's biggest amphibian.

Research carried out at London Zoo has confirmed that the Chinese giant salamander, previously classified as a single species (*Andrias davidianus*), actually consists of at least two other different species as well. Although once widespread throughout central, southern and eastern parts of China, these amphibians are now classified as critically endangered.

This discovery is likely to make conserving the largest members of the salamander group a much more complex task. These giants of the amphibian world typically grow up to 1.8m (6ft) in length and weigh up to 59kg (130lb). They feed on a wide variety of other aquatic life, from invertebrates to fish, with cannibalism also not being uncommon.



This painting portrays the newly-identified South China giant salamander *(Andrias sligoi)*. Photo © ZSL.

The value of museum collections

Emphasising the value of museum collections in zoological research work, the scientists at London Zoo analysed 17 historical museum specimens, and also tissue samples from wild salamanders while carrying out their investigations. The results revealed three distinct genetic lineages existed in giant salamanders from the different river systems and mountain ranges where they are to be found across China. There was also sufficient genetic variance in the samples to indicate that they were derived from separate species: *Andrias davidianus*, *Andrias sligoi*, and a third species which has yet to be named.

Early suspicions

The existence of one of the newly-identified species, the South China giant salamander (*Andrias sligoi*), was first proposed during the 1920s, based on an unusual individual from southern China that was then living at London Zoo. This idea was not accepted at the time, however, but it has finally been confirmed by this new study.

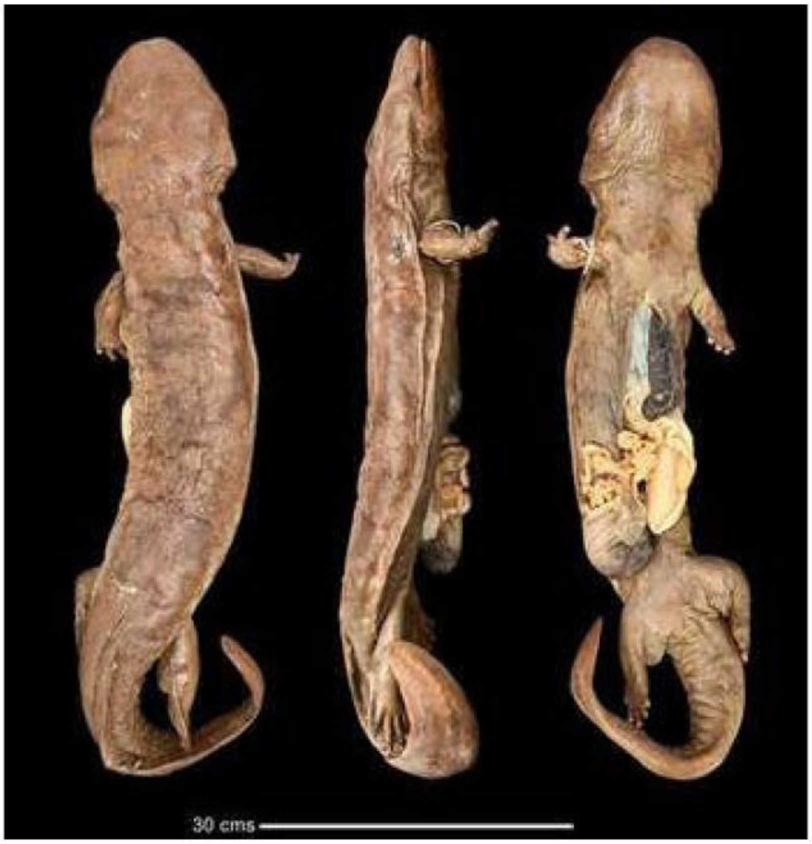
The team used the same animal, now preserved as a specimen in the Natural History Museum after living for 20 years at the Zoo, to define the characteristics of this previously unrecognised species. The other unnamed new species, originating from Huangshan (or the Yellow Mountains) was only identified from tissue samples, and, in the absence of an actual specimen, unfortunately it cannot be accurately described and officially named at present.

Isolation and the issues today

Professor Samuel Turvey of ZSL's Institute of Zoology, who led the study, says: "Our analysis reveals that Chinese giant salamander species diverged between 3.1 and 2.4 million years ago. These dates correspond to a period of mountain formation in China as the Tibetan Plateau rose rapidly, which could have isolated giant salamander populations and led to the evolution of distinct species in different landscapes.

"The decline in wild Chinese giant salamander numbers has been catastrophic, mainly due to recent overexploitation for food," he adds. "We hope that this new understanding of their species diversity has arrived in time to support their successful conservation, but urgent measures are required to protect any viable giant

▲ **There is some variation in colouration between the different species of giant salamander, linked with separate identities, so it has now emerged.** Photo courtesy tristan tan/www.shutterstock.com



It was this museum specimen of a Chinese giant salamander, which once lived at ZSL London Zoo, that has now been identified as one of the new species of giant salamander, and ranks as the world's biggest amphibian. Photo courtesy © Natural History Museum.

The giant salamander seen in close-up. Photo courtesy © ZSL/Ben Tapley.

salamander populations that might remain.

"Unfortunately, these salamanders are currently moved widely around China, for conservation translocation and to stock breeding farms that cater for China's luxury food market. Conservation plans must now be updated to recognise the existence of multiple giant salamander species, and movement of these animals should be prohibited to reduce the risk of disease transfer, competition, and genetic hybridisation."

The researchers suggest that the newly-discovered South China giant salamander – which can reach nearly 2m (6.5ft) – is the biggest of the three and is therefore the largest of the 8,000 or so amphibian species alive on the planet today.

Looking to the future

ZSL works in China to protect giant salamanders in the wild and to raise their profile through their exhibit at London Zoo, where zookeepers welcomed four juveniles in September 2016. These particular giant salamanders were seized by Border Force after an attempt to illegally import them.

One of the salamanders, named Professor Lew, has since moved into a state-of-the-art tank in the Zoo's Reptile House, where visitors can come face-to-face with one of nature's giants. The three others are currently being cared for behind the scenes. Keepers will eventually introduce another animal to Professor Lew as a mate and the remaining two may then move to a different zoo, as the adults are highly territorial and need to be housed in separate enclosures.

Melissa Marr from the Natural History Museum, London, another member of the research team, adds: "These findings come at a time when urgent interventions are required to save Chinese giant salamanders in the wild. Our results indicate that tailored conservation measures should be put in place to preserve the genetic integrity of each distinct species. This research also highlights the central role that the Natural History Museum's collections can play in the conservation of critically endangered species."

These salamanders are very well-camouflaged, and have small eyes. Photo courtesy tristan tan/ www.shutterstock.com

Further reading

Samuel T. Turvey, Melissa M. Marr, Ian Barnes, Selina Brace, Benjamin Tapley, Robert W. Murphy, Ermi Zhao, Andrew A. Cunningham. **Historical museum collections clarify the evolutionary history of cryptic species radiation in the world's largest amphibians.** *Ecology and Evolution*, 2019; DOI: 10.1002/ece3.5257

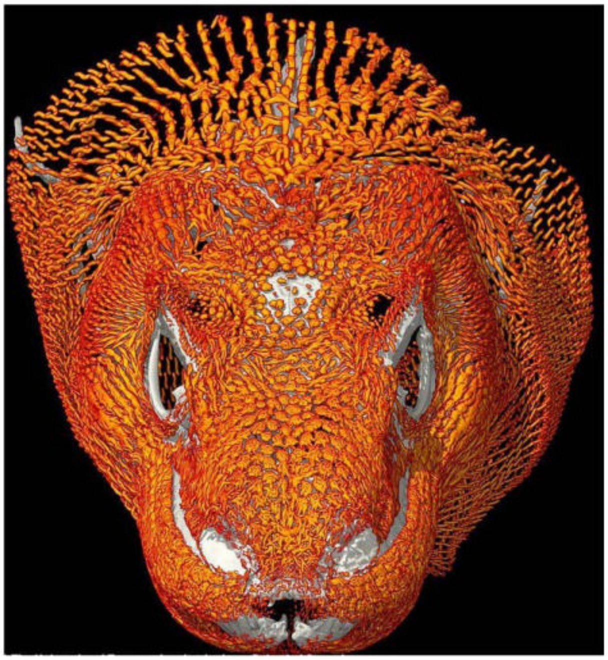
The armoured dragon

Just beneath their scales, Komodo dragons wear a suit of armour made of tiny bones. These bones cover the dragons from head to tail, creating a "chain mail" that protects the giant predators. However, the armour raises an important question: what does the world's largest lizard – being the dominant predator in its natural habitat – need protection from?

After scanning Komodo dragon specimens with high-powered X-rays, researchers at The University of Texas at Austin think they now have an answer: others of their own kind! The scientists came to their conclusion by using computed tomography (CT) technology to look inside and digitally reconstruct the skeletons of two deceased dragon specimens – one of an adult and the other of a baby.

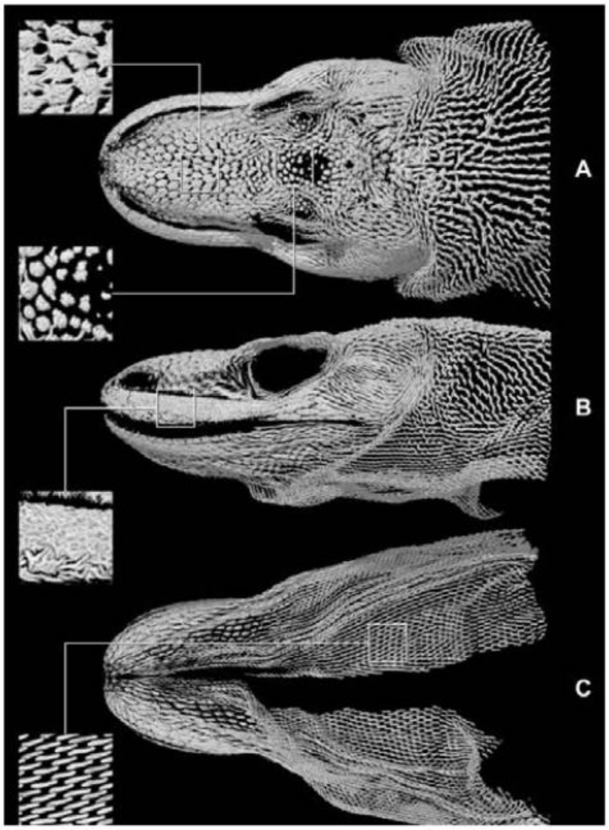
Contrasting findings

The adult was well-equipped with armour, but this was completely absent in the youngster. It's a finding that suggests that the bony plates don't appear until adulthood. And the only thing adult dragons need



▲ **A scan showing the bony areas protecting the skull of the adult Komodo dragon.** Image © The University of Texas at Austin/Jackson School of Geosciences.

▲ **Komodo dragons are arboreal as youngsters, lessening the risk of falling victim to their larger relatives on the ground. Their sharp claws are useful in terms of helping them to climb, and they are well-camouflaged too.** Photo courtesy Kjersti Joergensen/www.shutterstock.com



▲ **The Komodo dragon's osteoderms. The insets show the four basic osteoderm shapes found on the adult specimen, and their locations on the head. From top to bottom: rosette; platy; dendritic and vermiform.**
Image © The University of Texas at Austin/Jackson School of Geosciences.

Komodo dragons fighting. They are quite aggressive by nature.
Photo courtesy Sergey Uryadnikov/www.shutterstock.com

protection from is other dragons.

"Young Komodo dragons spend quite a bit of time in trees, and when they're large enough to come out of the trees, that's when they start getting in arguments with members of their own species," researcher Christopher Bell explains. "That would be a time when extra armour would certainly help."

Many groups of lizards have bones called osteoderms embedded in their skin. Scientists have known about osteoderms in Komodo dragons since at least the 1920s, when naturalist William D. Burden noted their presence as an impediment to the mass production of dragon leather. But since the skin is the first organ removed when making a skeleton, scientists do not have much information about how they are shaped or arranged inside the skin.

High-tech investigations

The researchers were able to overcome this issue by examining the dragon specimens at UT's High-Resolution X-ray Computed Tomography Facility, which is managed by Maisano. The lab's CT scanners are similar to a clinical CT scanner but use higher-energy X-rays and finer detectors to reveal the interiors of specimens in great detail.

As a result of the size constraints of the scanner, the researchers only scanned the head of the adult Komodo dragon, which measured nearly 2.75m (9ft) overall and had been donated by the Fort Worth Zoo in Texas when it passed away at 19½ years old. The San Antonio Zoo donated the 2-day-old baby specimen.

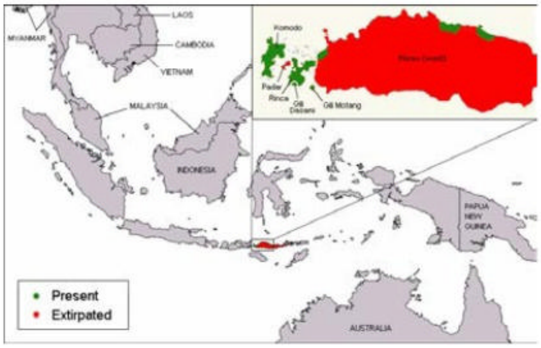
Unexpected findings

The CT scans revealed that the osteoderms in the adult Komodo dragon were unique among lizards, in terms of both their diversity of shapes and sheer coverage. Whereas the heads of other lizards examined by the researchers for comparison usually had one or two shapes of osteoderms, and sometimes large areas free of them, the Komodo dragon possessed four distinct shapes and a head almost entirely encased in this protective armour. The only areas lacking osteoderms on the head of the adult Komodo dragon were around the eyes, nostrils, mouth margins and the pineal eye, a light-sensing organ on the top of the head.

"We were really blown away when we saw it," Maisano reveals. "Most monitor lizards just have these vermiform (worm-shaped) osteoderms, but this guy has four very distinct morphologies, which is very unusual across lizards."

The adult dragon that the researchers examined was among the oldest known Komodo dragons living in captivity when it died. Maisano said that the advanced age may partially explain its extreme armour; as lizards age, their bones may continue to ossify, adding more and more layers of material, until death. She said that more research on Komodo dragons of different ages should help to reveal how their armour develops over time – and may help to pinpoint when these giant lizards first start to prepare for battle with other dragons.

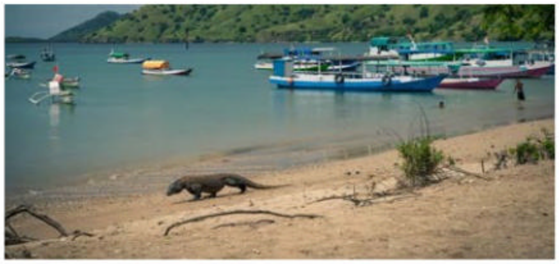
Komodo tourist charges announced



The present and former range of the Komodo dragon.
Map courtesy Tommyknocker/PD.

Concerns over the number of tourists visiting the island of Komodo — where these giant lizards were discovered just over a century ago, in 1910 — have been growing, and there were proposals under discussion to close the island to visitors from 2020. Siti Nurbaya Bakar, Indonesia's environment and forestry minister, has confirmed, however, that it has now been decided to replace this plan instead with a membership fee of US $1000 (£800) for visitors keen to see these gigantic lizards, which can grow to 3m (10ft) long, in their natural environment.

As to whether this would also extend to the nearby island of Rinca, home to just over 1000 dragons, is currently unclear. During 2020, the Komodo National Park had 176,000 visitors. Dragon numbers on Komodo — which is home to the largest population of about 1700 of these monstrous lizards — have been stable for over a decade, but there are fears that their food sources are being curbed by poaching. However, attempts to move residential communities from the island have been dismissed, and the plan instead is to help to improve the ranger service on the islands instead, and set up a research centre, which would be funded by the visitor fees.



Large numbers of tourists are now visiting the Komodo Islands, raising fears about their impact on the dragons there.
Photo courtesy Michele Rinaldi/www.shutterstock.com

Further information

Jessica A. Maisano, Travis J. Laduc, Christopher J. Bell, Diane Barber. **The Cephalic Osteoderms of *Varanus komodoensis* as Revealed by High-Resolution X-Ray Computed Tomography.** *The Anatomical Record*, 2019; 302 (10): 1675 DOI: 10.1002/ar.24197

Marwell Wildlife releases Britain's rarest lizard back into the wild

September 2019 was an important milestone for Marwell Wildlife, as the conservation charity released the final 80 juvenile sand lizards, the UK's rarest reptiles, at the Eelmoor Marsh Site of Special Scientific Interest, near Farnborough, Hampshire. This marks the last phase of a three-year release plan and research project.

Unexpected behaviour

Once common across heathlands of southern England, sand lizard numbers have decreased dramatically due to habitat loss and fragmentation. They are now only found in a handful of heathland and dune sites in southern England, Wales and Merseyside.

The focus of this intensive three year research, led by Rachel Gardner, a PhD student from Marwell Wildlife and University of Southampton, has been monitoring the animals following their release.

Rachel's research has included evaluating the behaviour, habitat use and survivorship of individuals (hatchlings and yearlings), which are uniquely identifiable by their individual spot pattern. The study has been able to observe differences in activity across age groups directly, as well as to gain insights into how they settle on the site.

Last year, as a first for the species following its reintroduction, tiny radio tags weighing less than 0.3g (0.01oz) were used to assess the lizards' activity within a complex microhabitat and build a clearer picture, with the aim of helping to conserve this cryptic species more effectively.

"We have seen some unexpected behaviours, for example, certain individuals travelled over a hundred metres (about 330ft) away from the release site within just a couple of weeks," says Rachel. "Considering the size of the animals, which measure just a few centimetres long, and the

⮝ **A sand lizard (*Lacerta agilis*)** Photo courtesy ahupepo/www.shutterstock.com

⮝ **The release area at Eelmoor Marsh.** Photo courtesy Marwell Wildlife.

One of Marwell's sand lizards released last year, fitted with its non-invasive tiny radio tag. Photo courtesy Paul Drane.

complexity of the heathland environment, this is quite a distance for them to be travelling in such a short space of time.

"It's been a privilege to work on this project and observe the sand lizards in such detail. Not only is Marwell Wildlife contributing to the wider reintroduction programme by breeding them in captivity for release into their natural environment, but we hope this research will help to inform and make recommendations for the reintroduction protocol in the future, and therefore help to optimise the conservation benefits," she adds.

A long-standing involvement

Marwell Wildlife, which own and operate Marwell Zoo located near Winchester, is dedicated to restoring habitats and conserving locally extinct species. As part of this project, the zoo itself is home to a captive breeding population of sand lizards in a custom-built vivarium, which is off-display to the public.

Each year, eggs are carefully excavated and artificially incubated to optimise the number of youngsters produced. Hatching occurs after 6-7 weeks and biometrics (measurements) of the juvenile lizards are then taken before they are transferred to smaller outdoor vivariums until they are released.

This year's release brings the total count of sand lizards reintroduced to Eelmoor Marsh to over 240 individuals, with the aim to establish a self-sustaining population, at a site which would have fallen within the species' indigenous range.

Marwell has been breeding sand lizards for release for more than 25 years. Photo courtesy Marwell Wildlife.

Eelmoor Marsh, owned by QinetiQ and managed by Marwell Wildlife, has been restored to a favourable condition following more than 20 years of targeted habitat management. Being in an area that is not open to the public, so this has allowed Rachel to monitor details of the sand lizards' ecology closely, with no unnatural disturbances.

Marwell Wildlife, in conjunction with key partners including the Amphibian and Reptile Conservation Trust and with support from Natural England, has contributed over 2,000 sand lizards for release across parts of southern England, and aims to continue working to conserve this specialist heathland species in the future, although this phase of the Eelmoor Marsh project is drawing to a close.

One of the lizards being monitored with its transmitter. Photo courtesy Marwell Wildlife.

Rachel and other team members working at the release site. Photo courtesy Marwell Wildlife.

Further information

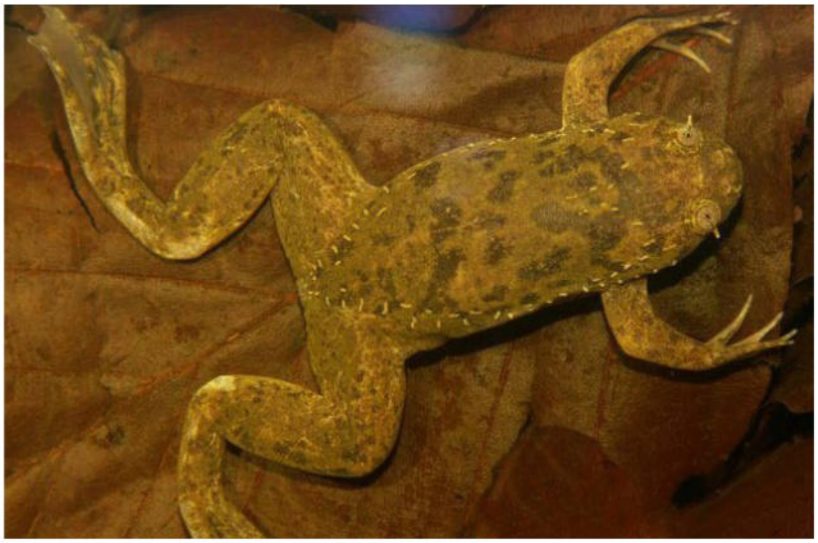
https://www.marwell.org.uk/zoo/

New clawed frog insights

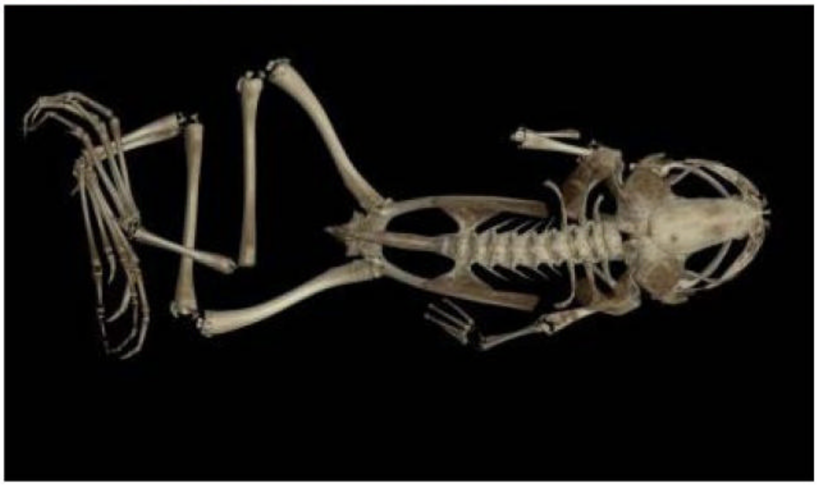
An international team of scientists, led by researchers at McMaster University in Ontario, Canada has solved a long-standing mystery surrounding Fraser's clawed frog, an unusual and elusive species found in West Africa. The findings dispel previous myths and shed new light on *Xenopus fraseri* including its geographic origin, evolutionary relationships, ecology, and distinctive species traits.

Two specimens of this frog, with a distinctive combination of four claws on their hind legs, as well as small bony protrusions on the roof of their mouths known as vomerine teeth, were collected by British zoologist Louis Fraser in 1852 and passed into the collection of the Natural History Museum (NHM) in London.

In 1905, Fraser's clawed frog was designated as a distinct species, but its place on the evolutionary tree, its geographic distribution, and ecology has since stumped scientists — due to a lack of genetic samples and inadequate records surrounding its origins.



➤ **Fraser's clawed frog.** Photo courtesy Václav Gvoždík/http://calphotos.berkeley.edu/CC BY-SA 2.5



➤ **A CT scan of *Xenopus fraseri*.** Image courtesy Edward L. Stanley.

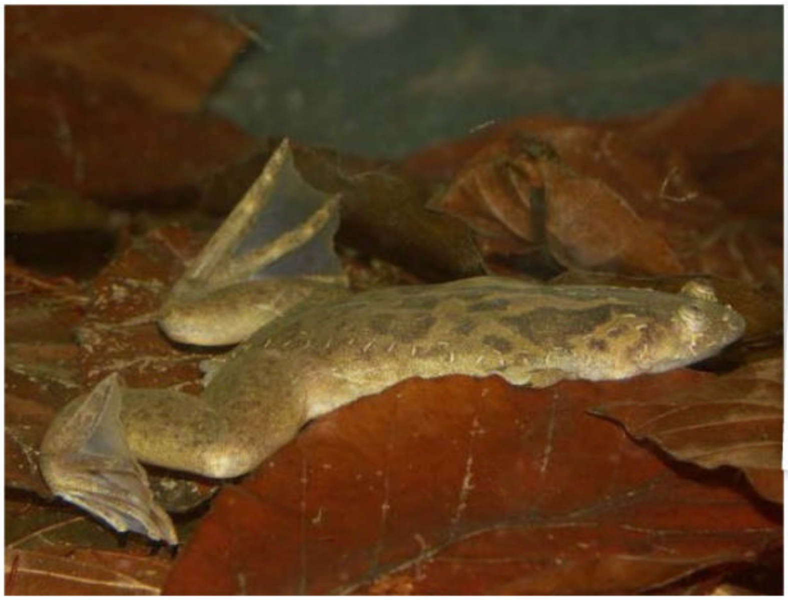
Difficult challenges

"The accurate identification of species is so important because it allows us to study change in populations, better understand how evolution occurs, and explore the processes that drive diversification, extinction and adaption," explains Ben Evans, a professor of biology at McMaster University, who led the new study into this elusive amphibian. "Yet the ancient condition of the only two specimens available to us posed many challenges for understanding its distinctiveness, using DNA and knowing exactly where they came from in the first instance."

This species is a relative of the well-known African clawed frog (*Xenopus laevis*) seen here. Photo courtesy Milan Zygmunt/www.shutterstock.com

The team, which included researchers from the NHM, the Max Planck Institute in Germany and the University of Florida, used sensitive techniques — similar to approaches used to sequence the genomes of Neanderthals — to sequence the mitochondrial genome from these delicate, aged specimens.

In addition, scientists sequenced complete or nearly complete mitochondrial genomes from 29 other *Xenopus* species, used high-resolution



This photo of Fraser's clawed frog reveals the very flat body shape of this group of amphibians. Photo courtesy Václav Gvoždík/http://calphotos.berkeley.edu/CC BY-SA 2.5

One of the two old specimens of this species - which dates back nearly 115 years! Photo © Trustees of the Natural History Museum.

CT scanning to compare the internal and external anatomy of these and other specimens and, through intensive field work, managed to collect additional specimens of Fraser's frog in several remote regions of West Africa.

Discoveries made

By doing so, the researchers finally determined that Fraser's clawed frog was indeed distinct from all others. And while it was previously thought to have lived in lowland tropical forests in West Africa, researchers found it actually inhabits the relatively hot and arid regions of northern Cameroon and northern Ghana.

"Obtaining DNA from specimens that have been preserved in spirit for well over a hundred years is something that has only become achievable in the last few decades. The recent advances in DNA extraction and sequencing are allowing us to revisit specimens and challenge assumptions made in the past," says Jeff Streicher, senior curator of amphibians and reptiles at the NHM.

As the next stage in this research, during the summer of 2020, the team plans to travel to Nigeria to continue their efforts to understand the biodiversity and genome evolution of African clawed frogs.

Further information

Ben J. Evans, Marie-Theres Gansauge, Edward L. Stanley, Benjamin L. S. Furman, Caroline M. S. Cauret, Caleb Ofori-Boateng, Václav Gvoždík, Jeffrey W. Streicher, Eli Greenbaum, Richard C. Tinsley, Matthias Meyer, David C. Blackburn. ***Xenopus fraseri*: Mr. Fraser, where did your frog come from?** PLOS ONE, 2019; 14 (9): e0220892 DOI: 10.1371/journal.pone.0220892

It has now been discovered that these frogs originate from relatively dry localities, as in Cameroon, shown here. Photo courtesy Scarabea/www.shutterstock.com

Identity crisis rewrites beetle family tree

There are more different kinds of beetle than just about any other type of animal—scientists have described approximately 5,800 different species of mammals, compared with nearly 400,000 species of beetles. And out of this total number of beetle species, more than 64,000 species are members of the rove beetle family, Staphylinidae. These mostly small earwig-looking insects are found all over the world, and they've been around since the time of the dinosaurs.

Yet scientists are still figuring out exactly when rove beetles first evolved. A new study indicates that the fossil beetle species believed to be the oldest rove beetle isn't a rove beetle at all, meaning the beetle family tree needs a significant rewrite.

The Hercules beetle (*Dynastes hercules*), seen here in Ecuador, is the longest and one of the biggest beetles in the world, measuring 18cm (7.5in) overall. It is also one of the world's largest flying insects.

Photo courtesy feathercollector/www.shutterstock.com

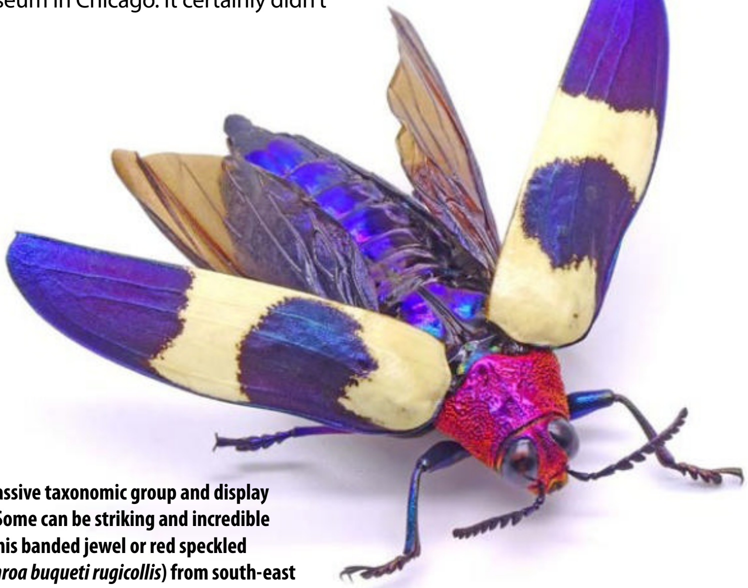
How it happened

The beetle at the centre of this mix-up, measuring about 2mm (0.08in) in size, is *Leehermania prorova*. When the fossils of *Leehermania* were first discovered in the 1990s along the Virginia and North Carolina border in the USA, they were believed to be the oldest rove beetles ever discovered — by about 50 million years.

Until 2012, the only public information on the fossils was two images, published in 1996 and 2005, but no formal description. Anyone who didn't have direct access to the fossils of the species could only make guesses about its placement in the tree of life based on those photos. So, when a formal description of the beetle was finally published, beetle scientists around the world were excited to read it.

"When *Leehermania* was formally described, and once more photos came out, we thought to ourselves: that doesn't look quite right for a staphylinid!" says Margaret Thayer, a scientist at the Field Museum in Chicago. It certainly didn't look like the rove beetles that Thayer has spent her career studying.

"I happened to be at the museum when I first read the paper, so I went and looked through the specimens in our collection for comparison," adds Alfred Newton, another Field Museum scientist who contributed to this new research. His hunch was that this beetle might be more closely related to Hydroscaphidae, a living family of miniature insects known as skiff beetles, placed in a different suborder from rove beetles.



Beetles are a massive taxonomic group and display huge diversity. Some can be striking and incredible beautiful, like this banded jewel or red speckled beetle (*Chrysochroa buqueti rugicollis*) from south-east Asia, which is classified in the Buprestidae family.

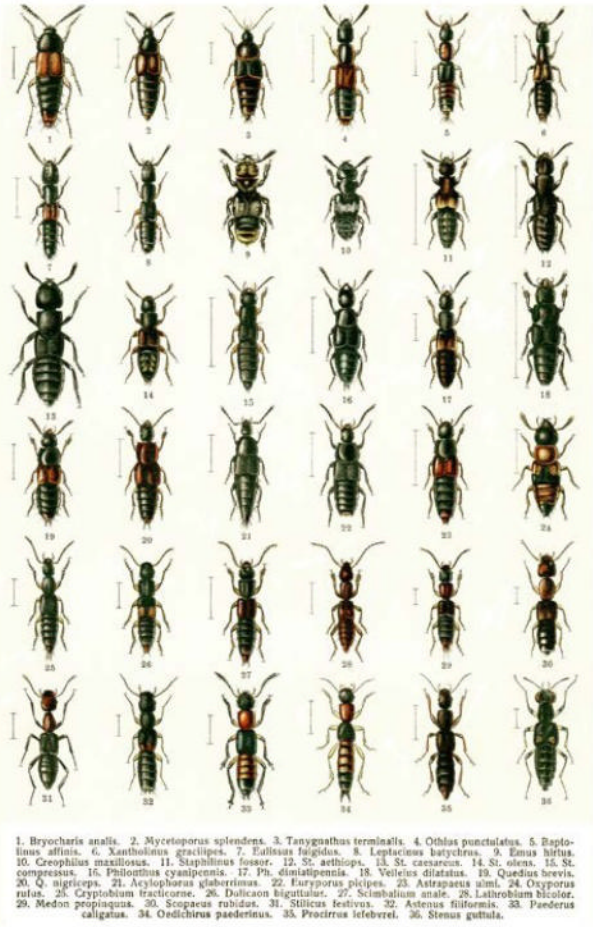
Photo courtesy Mark Brandon/www.shutterstock.com

Growing doubts

Meanwhile, across the Atlantic, Martin Fikáček recalled a similar feeling upon comparing the description and photos with the classification of *Leehermania* as a staphylinid. To Fikáček, a scientist at the National Museum in Prague, the beetle seemed to be a closer fit in the Myxophaga — the suborder that contains skiff beetles. Scientist Chenyang Cai at China's Nanjing Institute of Geology and Paleontology and several other scientists came to the same conclusion.

One of the clues that *Leehermania* wasn't really a staphylinid was its mandibles —the pincer-like jaws. "Staphylinids all have exposed mandibles, from at least some angle," argues Newton. "In *Leehermania*, what were originally interpreted as mandibles are actually maxillary palpi — a different mouthpart structure entirely. The mandibles aren't exposed here at all, at least from what we can see."

Another hallmark of staphylinid beetles is their somewhat club-shaped antennae, which start with a narrow base and get wider toward


1. Bryocharis analis. 2. Mycetoporus splendens. 3. Tanygnathus terminalis. 4. Othius punctulatus. 5. Baptolinus affinis. 6. Xantholinus gracilipes. 7. Eulissus fulgidus. 8. Leptacinus batychrus. 9. Emus hirtus. 10. Creophilus maxillosus. 11. Staphilinus fossor. 12. St. aethiops. 13. St. caesareus. 14. St. olens. 15. St. compressus. 16. Philonthus cyanipennis. 17. Ph. dimiatipennis. 18. Velleius dilatatus. 19. Quedius brevis. 20. Q. nigriceps. 21. Acylophorus glaberrimus. 22. Euryporus picipes. 23. Astrapaeus ulmi. 24. Oxyporus rufus. 25. Cryptobium fracticorne. 26. Dolicaon biguttulus. 27. Scimbalium anale. 28. Lathrobium bicolor. 29. Medon propinquus. 30. Scopaeus rubidus. 31. Stilicus festivus. 32. Astenus filiformis. 33. Paederus caligatus. 34. Oedichirus paederinus. 35. Procirrus lefebvrei. 36. Stenus guttula.

⮝ A selection of rove beetles in the family Staphylinidae, as portrayed in Georgiy Jacobson's book *Beetles of Russia and Western Europe*, which was published in different editions between 1905 and 1915, highlighting their rather earwig-like appearance. Source PD.

the tip. In *Leehermania*, the antennae were club-shaped, but the club in this case was more narrowed toward the tip.

Given the hidden mandibles, distinct antennal shape, and other features, including "paratergites" — little plates on the sides of most staphylinid abdomens that are absent in *Leehermania* — and the shape of the female insects' genitalia, something wasn't adding up. *Leehermania* seemed to be a much better fit in the suborder Myxophaga than in Staphylinidae.

International concerns increase

Thanks to the power of the internet, the scientists were able to collaborate freely and quickly across four continents. "The international collaboration that occurred here was really important to the success of the study," explains Shûhei Yamamoto, a Field Museum scientist who studies Staphylinidae and other beetles.

As the group's hunch turned to a theory, then a study, then a formal analysis, the tests they ran showed *Leehermania* fitting nicely as a member of the beetle suborder Myxophaga, likely as a sister to the ancestors of today's skiff beetles. This discovery means that the rove beetle family isn't yet documented to be as old as scientists thought, but the skiff beetle family is now way older — *Leehermania* lived 226 million years ago, which was 100 million years before the next oldest fossil skiff beetle known.

⮝ The detail from fossils may often be limited, sometimes because of viewing difficulties. Photo courtesy JonShore/www.shutterstock.com

Why mistakes happen

It's fair to say that misclassification of extinct species happens all the time in science, for a variety of reasons. For one thing, fossils can be extremely difficult to decipher. Since compression fossils like *Leehermania* are trapped in a sheet of rock, there is often only one viewing angle, though two in this case: a bird's-eye-view called 'dorsal', representing the top surface, and the 'lateral' or side view.

Any information about the species has to be gathered from these limited perspectives, so some information on colours, textures, patterns, anatomical details, and of course life-cycle information may be impossible to retrieve. Analysis is even more challenging when your specimens are only 2–3mm (0.08-0.11in) long.

Lack of comparative data also causes problems for researchers. Not only are many characteristics of the insects lost in fossils, but until 2011, the large amount of data used here to test *Leehermania*'s placement in different families didn't exist.

"Our analysis made use of a huge data set of morphological characters of beetles gathered for the 'Beetle Tree of Life' [BToL] project," says Thayer. "That project was really crucial to our analysis and provided a framework upon which we were able to analyse *Leehermania*."

Four authors of the new paper, including Thayer and Newton, were among the authors of the published version of the BToL morphology paper. DNA-based analyses published by the BtoL project and other researchers were also essential to the Leehermania analyses.

Potentially serious consequences

Testing and revising the placement of living things in the tree of life is like working on a huge sudoku puzzle with contributors from all over the world. You have methods to figure out where the numbers should go, but if they're incorrectly placed, you only know — eventually — based on their relationships to the surrounding numbers. If you carry on with the puzzle for too long with an incorrect placement, numbers filled in after the fact might also be incorrect.

⮝ Amber resin from conifers in areas such as the Baltic and the Dominian Republic has proved useful in revealing more about beetles, including rove beetles, trapping living specimens and preserving them in their entirety, over the course of millions of years.

Photo courtesy Bjoern Wylezich/www.shutterstock.com

Revisiting *Leehermania*'s classification was therefore very important to help other researchers avoid using the fossils incorrectly to date analyses of beetles as a whole, or identify other beetles as staphylinids based on *Leehermania*. For the staphylinid family however, losing their oldest ancestor produces new questions about how the family evolved.

"The re-classification of *Leehermania* means that staphylinids are now 50 million years younger than we thought," says Fikáček. "But if staphylinids are so much younger, that means that this family evolved into many lineages much more rapidly than we thought they did."

Older Staphylinidae fossils are of course likely to turn up in the future and new analyses will be needed. At a time in the Earth's history when life was still recovering after a mass extinction, the appearance of *Leehermania* and Staphylinidae is a testament to how resilient and adaptable beetles can be to diverse, and often harsh, living conditions.

"Throughout history, beetles have survived conditions that other animals have not," says Fikáček. "As we study these insects, we might reveal some secrets regarding the evolutionary success that beetles have had."

Insects adapting to climate change

A team of biologists led by researchers from Tufts University, Massachusetts has found two genes that may permit some insect species to survive climate change by adjusting their biological annual clocks, while others succumb. The ability to synchronise behavioural, morphological and other transitions with the seasons is integral to the lifecycle of most insects. The researchers looked at the European corn borer moth (*Ostrinia nubilalis*) and pinpointed variation in two circadian clock genes – known as per and Pdfr – that enable different populations of the moth to adapt their transitions to longer or shorter winters.

Signs of change

The length of winter is expected to decrease by a month over the next century, and as climate change is already underway, many insect species are experiencing profound effects. In some cases, this has contributed directly to the extended range of insect pests, like the corn borer moth and lanternflies, yet in other cases, beneficial pollinators have declined in numbers and range. But despite the importance of circannual rhythms to the ability of insects to adapt to rapidly changing environments, little is currently known about the underlying mechanisms of this phenomenon.

Earlier springtime activity and emergence from a dormant winter state (diapause) can allow insect populations to seek out and find favourable environments and to produce more generations per year, both of which improve the likelihood of insects surviving in the face of rapid environmental change.

Genetic involvement

By conducting a broad scan of the corn borer genome among five moth populations with varying diapauses, this new research has discovered that the two genes correlating with this activity are the genes period (per) and pigment dispersing factor receptor (Pdfr). It seems likely that intense selection on variants of these two genes is likely to be important to adaptation and range expansion as global climate change continues in the future.

"We can now start to look at these genes in other insects, to see how variation might be linked to changes in timing for when they go dormant before winter, and when they 'wake up' in the spring," says Genevieve Kozak, the lead researcher from Tufts University's Department of Biology. "By knowing a little bit about the proteins these genes code for, we can start connecting molecular mechanisms to insect behaviour, and also their physiological response to climate."

Short term and long term impacts

Both per and Pdfr are known to interact with circadian rhythms in insect brains, where their role is to synchronise biological activity to the daily cycles of night and day. It is interesting to note that these two genes and their products, known to coordinate short term biological cycles, have been discovered in this study also to be important for long term, annual cycles. It therefore seems likely that there is a linkage between the daily clock and the seasonal timer.

⮝ The corn borer moth - a pest species which appears well-equipped to survive and thrive, in spite of climate change, thanks to its genes. Photo courtesy phichak.www.shutterstock.com

⮟ The larvae of the European corn borer can be serious pests of corn cobs and grains too. Photo courtesy Tomasz Klejdysz/www.shutterstock.com

"Although we still have a long way to go, the completion of the molecular picture can help biologists not just understand but possibly predict and anticipate the impact of climate change on different insect species," adds Erik Dopman, professor of biology at Tufts University School of Arts and Sciences. "We can use that information to help guide both conservation and pest management efforts."

⮝ Some butterflies, like the red admiral (*Vanessa atalanta*) will hibernate, emerging early in spring. Much still remains to be learnt about genetic involvements in this area in insects generally.

Photo courtesy GerDuess/www.shutterstock.com

⮝ Lanternflies represent another group of insect pests to have benefitted from climate change. These are spotted lanternflies (*Lycorma delicatula*). Photo courtesy Jana Shea/www.shutterstock.com

Further information

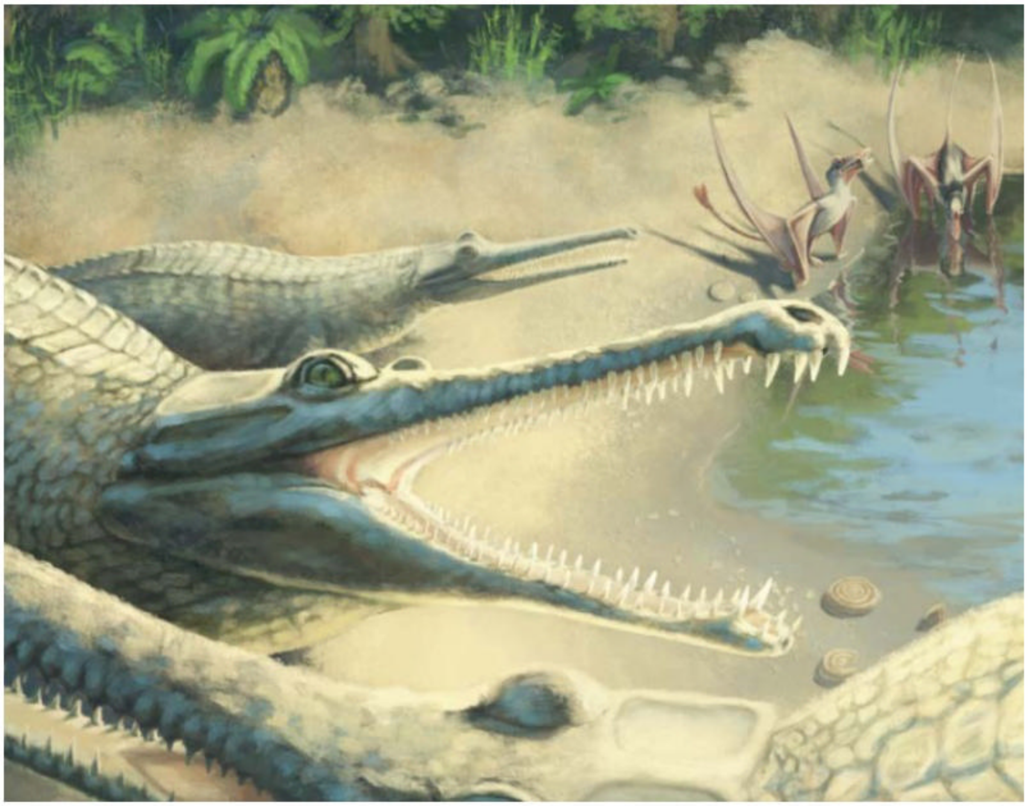
Kozak, G.M., Wadsworth, C.B., Kahne, S.C. Bogdanowicz, S.M., Harrison, R.G., Coates, B.S. & Dopman, E.B. **Genomic basis of circannual rhythm in the European corn borer moth.** *Current Biology*, 2019 https://www.biorxiv.org/content/10.1101/633362v1.full

New crocodile identified – after 250 years!

A prehistoric crocodile that lived around 180 million years ago has been identified – almost 250 years after the discovery of its fossilised remains. The skull that was found during the 1770s in a Bavarian town has finally been recognised as the now-extinct species *Mystriosaurus laurillardi*, which lived in tropical waters during the Jurassic Period.

For the past 60 years, it was thought the animal belonged to a similar species, known as *Steneosaurus bollensis*, which existed around the same time. Palaeontologists have now identified the crocodile by analysing fossils unearthed in the UK and Germany. The team, which included Edinburgh scientists, also revealed that another skull, discovered in Yorkshire in the 1800s, belongs to *Mystriosaurus laurillardi*.

"Unravelling the complex history and anatomy of fossils like *Mystriosaurus* is necessary if we are to understand the diversification of crocodiles during the Jurassic. Their rapid increase in biodiversity between 200 and 180 million years ago is still poorly understood," explains Dr Mark Young, based at the University of Edinburgh's School of GeoSciences.

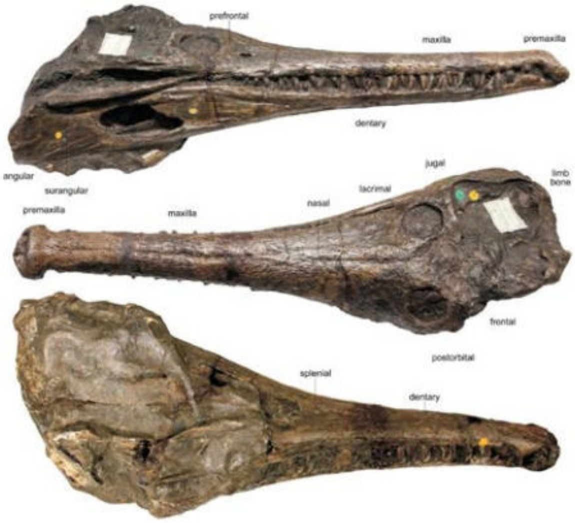


▲ **A reconstruction of the likely appearance of *Mystriosaurus laurillardi*.**
Artwork courtesy Julia Beier.

Marine species

The marine predator — which was more than 4m (13.1ft) in length — had a long snout and pointed teeth, and preyed on fish, the team says. It lived in warm seas alongside other animals including ammonites and the large marine reptiles known as ichthyosaurs.

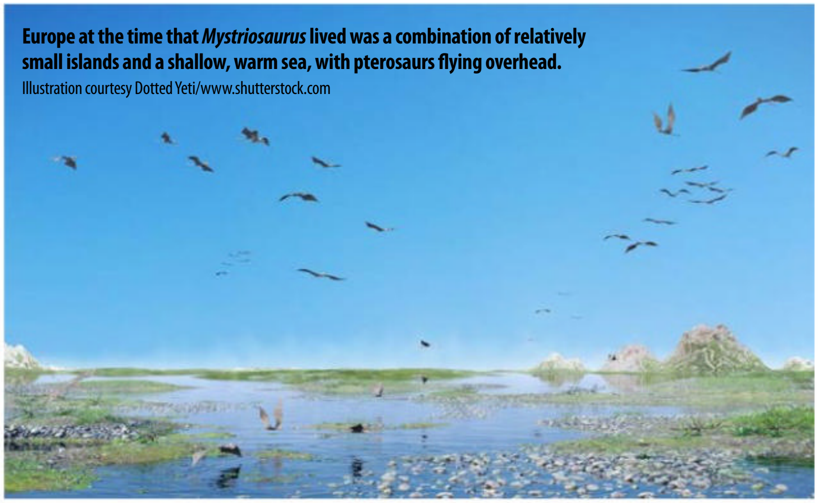
The discovery of fossils in present-day Germany and the UK shows that the species could easily swim between islands, much like modern saltwater crocodiles, according to the researchers. "*Mystriosaurus* looked like a gharial but it had a shorter snout with its nasal opening facing forwards, whereas in nearly all other fossil and living crocodiles, the nasal opening is placed on top of the snout," explains Sven Sachs from the Naturkunde-Museum Bielefeld in Germany.



▲ **This specimen, unearthed in in the English county of Yorkshire, is now regarded as being from *Mystriosaurus laurillardi* too.** Illustration courtesy Sven Sachs, Michela M. Johnson, Mark T. Young, and Pascal Abel - http://app.pan.pl/article/item/app005572018.html

Further information

Sven Sachs, Michela M. Johnson, Mark T. Young, and Pascal Abel. **The mystery of *Mystriosaurus*: Redescribing the poorly known Early Jurassic teleosauroid thalattosuchians *Mystriosaurus laurillardi* and *Steneosaurus brevior*.** *Acta Palaeontol.*, Pol. 64 (3): 565%u2013579, 2019 DOI: 10.4202/app.00557.2018



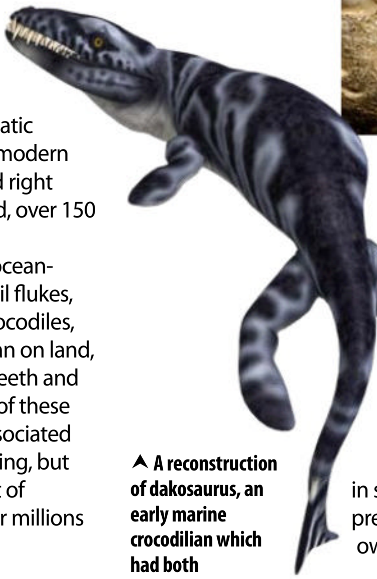
Europe at the time that *Mystriosaurus* lived was a combination of relatively small islands and a shallow, warm sea, with pterosaurs flying overhead.
Illustration courtesy Dotted Yeti/www.shutterstock.com

What ancient crocodiles ate

Photo courtesy Nagel Photography/www.shutterstock.com

While most people imagine alligators and crocodiles as being much the same now as they were during the age of dinosaurs, digging into the fossil record shows species used to be much more diverse. Nevertheless, semi-aquatic ambush predators resembling modern alligators and crocodiles existed right back as far as the Jurassic period, over 150 million years ago.

Yet the group also included ocean-going crocs with flippers and tail flukes, heavily armoured pug-faced crocodiles, others that had long legs and ran on land, plus giant crocodiles with tiny teeth and surfboard-shaped skulls. Many of these odd adaptations seem to be associated with what the animals were eating, but how do scientists study the diet of animals that have been dead for millions of years?

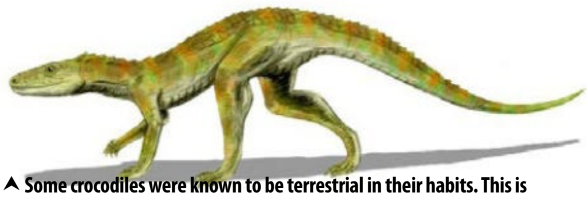

⮝ **A reconstruction of dakosaurus, an early marine crocodilian which had both paddle-like limbs and a similar tail.** Illustration courtesy Ralf Juergen Kraft/www.shutterstock.com

Forensic dieticians?

Two researchers — one from the University of Tennessee, Knoxville, and one from Stony Brook University — have tried to tackle this question by bringing together mathematical analyses of the animals' shapes, surveys of modern crocodiles' diet, modelling methods for reconstructing the diet of fossil groups, and forensic-style interpretations of damaged bones from the distant past.

"We used to put modern crocs into two ecological bins: slender-snouted groups which eat only fish, and broader-snouted groups which eat pretty much whatever they want," says palaeontologist Stephanie Drumheller, an adjunct assistant professor in UT's Department of Earth and Planetary Sciences. "But as is often the case, the reality is a lot more complicated."

Slender-snouted crocodiles, such as Indian gharials and Australian freshwater crocodiles, actually eat all sorts of animals other than fish, although they do tend to stick with smaller prey relative to their body size. Among those that eat larger prey, the researchers found an unexpected split. Broad V-shaped snouts, like those seen in American crocodiles, correspond with animals that are able to eat prey species up to their own size. More U-shaped snouts, like those associated with American alligators, can often be found in species that take down even larger prey — sometimes close to twice their own body weight.


⮝ **Some crocodiles were known to be terrestrial in their habits. This is *Hesperosuchus gracilis*, from the Late Triassic of North America.**
Artwork courtesy Nobu Tamura (http://spinops.blogspot.com)/CC BY-2.5.

Significant variation

"Several of these fossil groups had skulls and teeth wildly different from living species. This suggests that the way they fed also differed dramatically," explains colleague Eric Wilberg, an assistant professor in Stony Brook University's Department of Anatomical Sciences.

Among these are a group of extinct crocodiles that lived in the oceans. While they had slender snouts similar to those of living gharials, their eyes were positioned more on the side of the head, and the part of the skull that houses the jaw muscles was enlarged. This suggests they were not ambush predators like modern crocodylians.

Another group consists almost exclusively of species that lived on land. These crocs had flattened, serrated teeth, like those of carnivorous dinosaurs, and their eyes were positioned significantly on the side of the head.

Palaeontologists obviously cannot observe feeding in extinct groups, but the fossil record sometimes provides snapshots of this behaviour. "Crocodiles and their relatives are pretty messy eaters," explains Drumheller. "That's great, because they'll often leave broken, bitten bones behind for us to find."

Diversity down the ages

Most of these fossil bite marks line up nicely with the idea of crocodiles and their relatives eating within their expected weight classes. The fossils that don't fit may be evidence of scavenging, a behaviour that is rarely testable in the fossil record.

Some crocodile groups nevertheless remain mysterious. No fossil bite marks exist for the stubby-faced crocodiles, whose complex teeth and weak jaws suggest they might have been plant eaters, or for the surfboard-headed ones, which had tiny teeth and may have sported pelican-like pouches under their long, wide jaws.

"Crocodiles and their relatives have long been thought of as being unchanged for hundreds of millions of years, and as a result, they have received less scientific attention than other groups like dinosaurs and mammals," observes Wilberg. "Yet renewed interest in these reptiles has consistently demonstrated a complex evolutionary and ecological history, going far beyond that of the semi-aquatic ambush predators alive today."

⮝ **The U-shaped snout of the American alligator is an indicator of a species able to take prey larger than itself.** Photo courtesy Kitch Bain/www.shutterstock.com

Further information

Stephanie K Drumheller, Eric W Wilberg. **A synthetic approach for assessing the interplay of form and function in the crocodyliform snout**. *Zoological Journal of the Linnean Society*, 2019; DOI: 10.1093/zoolinnean/zlz081

Bone disease in an ancient lizard

A lizard-like animal that lived 289 million years ago suffered from a bone condition similar to Paget's disease, according to a study by Yara Haridy of the Museum für Naturkunde in Berlin and colleagues. This is the most ancient known case of such a disease.

The animal in question belonged to an extinct group of lizard-like creatures called varanopids, which were relatives of the earliest ancestors of mammals or reptiles. The authors identified the disease in an isolated pair of tail vertebrae discovered in an Early Permian cave at Richards Spur, Oklahoma.

Micro-CT scanning allowed examination of both the external and internal structure, revealing that in some places, the bone had been thinned by excessively high levels of reabsorption, while in other areas, excessive bone growth had resulted in abnormal bone thickening and the ultimate fusion of the two vertebrae.

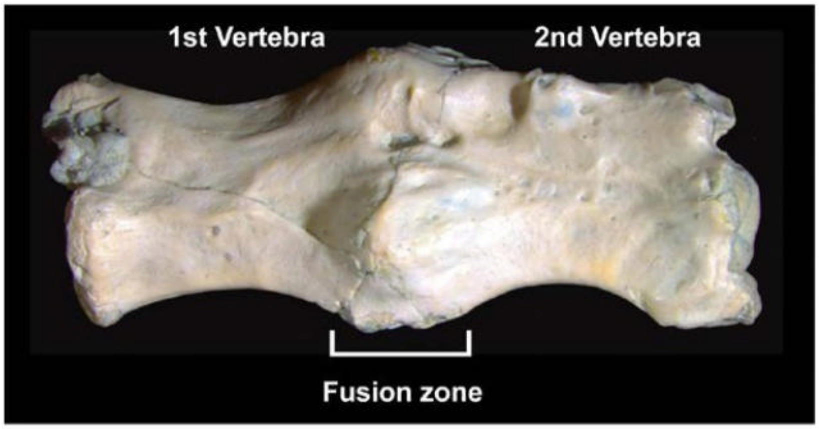
Documented in a dinosaur

According to the researchers, this condition is most similar to Paget's disease, a bone metabolic disorder marked by a breakdown in communication between bone building cells and bone destroying cells. Paget's disease is commonly seen today in the hips and vertebrae of humans and has been diagnosed in other living mammals and reptiles as well as one early Jurassic dinosaur fossil. The disease has been linked to both genetic and viral factors, though its precise cause remains controversial.

With only two vertebrae preserved, it is impossible to say how widespread the disease was in this animal's body. If it was restricted to the tail, the animal may only have suffered minor pain and stiffness. This discovery marks the oldest known occurrence of a Paget-like disease and suggests that susceptibility to such disorders was already present in our early Permian cousins.

⮝ Studies of fossils can give clear insight into some disease processes from the past, especially those affecting the skeleton.

Photo courtesy Nick Fox/www.shutterstock.com



⮜ This photo shows the pair of abnormal fused vertebrae.

Photo courtesy Yara Haridy/Museum für Naturkunde, Berlin.

A better understanding

Haridy adds: "Palaeopathology is the study of ancient diseases, and in this case, what we found was evidence of a bone disease similar to modern day Paget's disease. This enigmatic illness is still not well understood in humans, however finding something similar in an ancient animal likely links it to something deep in our bone biology.

"This study is a great example of how when palaeontologists find well-preserved fossils, we can now tell a lot more than just identifying the animals themselves. We can explore their biology, physiology and even what diseases affected them!"

Further information

Haridy Y, Witzmann F, Asbach P, Reisz RR (2019) **Permian metabolic bone disease revealed by microCT: Paget's disease-like pathology in vertebrae of an early amniote.** *PLoS ONE* 14(8): e0219662. https://doi.org/10.1371/journal.pone.0219662

Snakes stop breeding

A copperhead in the wild. © Photo by Chuck Smith

A long-term study of copperhead snakes *(Agkistrodon contortrix)* in a forest near Meriden, Connecticut, revealed that five consecutive years of drought effectively ended the snakes' reproductive output. Researchers found that not one of the dozens of female snakes in the closely monitored population produced young in the year after the drought ended. The year before that, only one female had reproduced successfully. In contrast, in the years before the drought, many of these snakes produced dozens of offspring.

"Before this study, we knew surprisingly little about how drought directly affects reproduction in snakes," explains Mark A. Davis, a conservation biologist with the Illinois Natural History Survey at the University of Illinois, who co-led the research with Charles (Chuck) F. Smith, of Wofford College.

Cicadas are an important food source for snakes. Researchers documented a boost in the snakes' reproductive output in the year after 17-year old cicadas emerged. Photo courtesy Catherine Dana.

Drought significantly altered the landscape in the area. Even under normal circumstances, water becomes scarcer - this area here is normally dry by July. Photo courtesy Jeff Holcombe/www.shutterstock.com

Changes in the landscape

As the drought wore on, several semipermanent wetlands - which normally fill with water during the autumn and winter and gradually dry out in late summer - became completely dry, the team found. "When the drought got really bad, the temporary wetlands were never wet," Davis says. "And the permanent wetlands became temporary wetlands."

Hartford
CONNECTICUT
RHO
ISLA
Waterbury
Meriden
New London
New Haven
Bridgeport

The study was carried out close to Meriden in the US state of Connecticut, which lies north of New York on the east coast. Photo courtesy sevenMaps7/www.shutterstock.com

Since copperheads prey on tadpoles, salamanders and other wetland-associated amphibians as part of their diet, the parched wetlands meant their prey was disappearing. A shortage of food results in poor body condition, preventing the snakes from reproducing successfully during the following year.

The cicada effect

Just before the multi-year drought began, however, another food source became available in great abundance for a time. A massive brood of cicadas emerged from the ground, with these invertebrates have a 17 year lifecycle!

Copperheads are known to gorge on cicadas when the insects emerge. The following year, in 2011, 20 females produced 148 young. This was the largest number recorded over the 10

Drought reduces the availability of food, impacting on the condition of the snakes.
Photo courtesy Chuck Smith.

Illinois Natural History Survey entomologist Catherine Dana, INHS conservation biologist Mark Davis and colleagues discovered that copperheads suffered reproductive declines in response to a severe multiyear drought.
Photo courtesy Fred Zwicky.

years that researchers had collected data.

But then in the following year, the drought began. The team wanted to know whether copperheads would produce fewer offspring in response to the drought and dwindling food supplies, or if they would produce the same number of young, but of a smaller size.

Persistent decline

"We saw that every year the drought wore on, there were fewer pregnant females, and the year after the drought ended there were no pregnant females at the site," Davis explains. Regardless of the conditions, snakes that gave birth always produced about six offspring, and the newborn snakes were roughly the same size from year to year, according to the team's results.

"This means that the snakes are effectively deciding whether they are able to produce offspring," says Davis. "And as the drought wore on, the answer became increasingly clear - this simply wasn't possible."

"The researchers were confident that they were capturing most or all of the pregnant females in the population over the years, he continues. "The snakes return each year to the same hibernation and gestation sites, making it relatively easy to find them."

Worrying findings

During 2018, after a year of normal precipitation, breeding success of the copperheads in the area rebounded. The researchers counted 100 offspring from 16 pregnant females. This group of pregnant females included individuals that had been captured and given birth in the past. The study revealed that, while copperheads are resilient, their ability to adapt to environmental change has limits.

As climate change stresses the entire ecosystem, the snakes may run out of alternate food supplies like the cicadas, which also are disappearing from many landscapes, according to cicada specialist Catherine Dana.

"This study shows that reproduction is complex," Davis adds. "A changing climate coupled with the loss of biodiversity may be placing even common species at higher risk of declines in the short term and, perhaps, extinctions in the long term. This will only serve to erode those ecosystem services - the benefits we receive from nature - that these animals provide."

Copperheads are neither endangered nor threatened in Connecticut, but extended droughts could lead to severe declines by eliminating their ability to reproduce, based on the results of this study. Photo by Chuck Smith

Further information

Charles F. Smith , Gordon W. Schuett, Randall S. Reiserer, Catherine E. Dana, Michael L. Collyer & Mark A. Davis. **Drought-induced Suppression of Female Fecundity in a Capital Breeder.** *Scientific Reports,* 2019 DOI: 10.1038/s41598-019-51810-9

Sniffing out their numbers

⮝ **The blunt-nosed leopard lizard was the subject of this study.** © Photo courtesy Jonathan Richmond.

Detection dogs specifically trained to sniff out the scat of an endangered lizard in California's San Joaquin Valley, combined with genetic species identification, could represent a new, non-invasive sampling technique for lizard conservation worldwide. That is according to a study carried out by the University of California, Davis, in partnership with the nonprofit Working Dogs for Conservation, the U.S. Geological Survey and the U.S. Bureau of Land Management (BLM).

A new approach

Scientists had previously used trained conservation dogs to locate scat (droppings) and collect DNA samples for everything from bears and foxes to gorillas and whales. But this technique had not been used for reptiles until this study. The scientists involved developed a novel approach to identify the presence of the blunt-nosed leopard lizard *(Gambelia sila)* in the Panoche Hills Recreation Area and Carrizo Plain National Monument, both managed by BLM. They used new methods to recover DNA from faeces, which allowed the genetic identification of lizard species occurring in the area.

⮝ **Deb Orbee out searching with her dog called Seamus, who has been specially trained to find the presence of lizards from their droppings.** Photo courtesy Mike Westphal.

⮝ **Seamus in a characteristic pose to alert his handler Deb to the fact that he has detected evidence of blunt-nosed leopard lizards at this spot.** Photo courtesy Mike Westphal.

Over 8 in 10 samples that the dogs detected were indeed from blunt-nosed leopard lizards. Photo courtesy Jonathan Richmond.

"So many reptilian species have been hit so hard in terms of their populations, for a variety of reasons," says lead author Mark Statham, an associate researcher with the Mammalian Ecology and Conservation Unit of the UC Davis School of Veterinary Medicine. "A large proportion of them are now endangered or threatened. This new approach is a really valuable way for people to be able to survey them."

No direct contact needed

Current methods for surveying lizard species typically rely on live capture or visual surveys. Scat sampling, however, allows biologists to study elusive, rare or dangerous animals without the need for direct contact. In addition to providing information about the presence, habitat and genetics of an animal, scat can also be analysed to provide much more information about its diet, hormones, parasites and other health issues as well.

Using the new method, the authors genetically typed a specific species in the case of 78 percent of the 327 samples collected by dog-handler teams over the course of four years. The majority of those (82 percent) identified were confirmed as being from blunt-nosed leopard lizards.

⮝ Laboratory follow-up being carried out by Mark Statham, with the aim of identifying the DNA that has been recovered. Photo courtesy Mark Statham/UC Davis.

In order to meet regulatory monitoring requirements, more research is needed to assess the viability of using detection dogs to recover usable DNA on larger scale surveys. But this research clearly highlights the very broad potential that this method offers for surveying and monitoring a diverse range of reptile populations.

Further information

Mark J. Statham, Deborah A. (Smith) Woollett, Susan Fresquez, Jerene Pfeiffer, Jonathan Richmond, Alice Whitelaw, Ngaio L. Richards, Michael F. Westphal, Benjamin N. Sacks. **Noninvasive Identification of Herpetofauna: Pairing Conservation Dogs and Genetic Analysis.** *The Journal of Wildlife Management*, 2019; DOI: 10.1002/jwmg.21772

Is there an Insect Armageddon underway?

Researchers who set out to test the widespread theory that the UK is experiencing an alarming plunge in insect numbers have found no evidence for the supposed Insect Armageddon. Instead, the researchers from the University of York found peaks and troughs in moth populations over a period of 50 years. They suggest changing weather patterns and climate change could be an explanation for this phenomenon.

The study tracked the amount of moths – which the researchers measured by estimating the combined weight, or "biomass" of all moths in a given area - between 1967 and 2017. The findings reveal there are around twice the combined weight of moths to be found today compared with the 1960s. While there has been a gradual decline in the amount of moths at a rate of around 10% per decade since the early 1980s, this came after a steep increase between the late 1960s and 1982.

⌃ **A large emerald moth *(Geometra papilionaria)*. These moths feed on birch trees, which are very sensitive to dry conditions and drought.** Photo courtesy Martin Fowler/www.shutterstock.com.

The findings

Dr Callum Macgregor, lead investigator from York's Department of Biology, explains: "Moths are a good indicator of what may also be happening in other insect populations as they are the second most diverse group of insect herbivores, with a full range of species extending from extreme habitat generalists to extreme specialists.

"Our study does not support the narrative that insects are vanishing *en masse* before our eyes, because there has been a net increase in biomass over the last 50 years. However, the clear decline we have observed since the 1980s is still a cause for concern.

"Moths come in all shapes and sizes, so measuring their combined weight allowed us to analyse changes in their populations that are relevant to their predators and food plants."

Fellow researcher Professor Chris Thomas, from the Department of Biology at the University of York, adds: "Biomass is particularly important because it is linked to ecosystem processes, such as the total amount of plant material consumed by insects and food availability for other animals that eat insects.

⌃ **Moths are important pollinators. This is a hummingbird hawk moth *(Macroglossum stellatarum)*.** Photo courtesy Cristian Gusa/www.shutterstock.com

⌃ **The elephant hawk-moth *(Deilephila elpenor)* has declined by 11% over the last 50 years, according to Rothamsted Insect Survey data.** Photo courtesy Chekaramit/www.shutterstock.com

"Moths act as nocturnal pollinators for a wide range of plants, and they also provide food for birds, bats and small mammals. Their survival is crucially important to the rest of life on earth."

National data

The authors also investigated the possible reasons behind the fluctuations in insect populations, and why the results of the study might differ from the conclusions of previous research.

According to the scientists, the use of

Woodland moths like this broad-bordered yellow underwing moth *(Noctua fimbriata)*, seen here on an oak tree, were amongst those showing the most significant declines. Photo courtesy Sandra Standbridge/www.shutterstock.com

better and longer-term data may be part of the answer.

In order to put the 'Insectageddon' theory to the test, they analysed data from "perhaps the best insect population database available anywhere in the world" - the Rothamsted Insect Survey's national network of light-traps.

The data allowed them to estimate the weight of moths caught each year at 34 different sites around the UK between 1967 and 2017. Dr James Bell from the Rothamsted Insect Survey explains: "Since 1964, this survey has been at the forefront of research into insect declines, using the longest standardised terrestrial insect timeline of populations in the world.

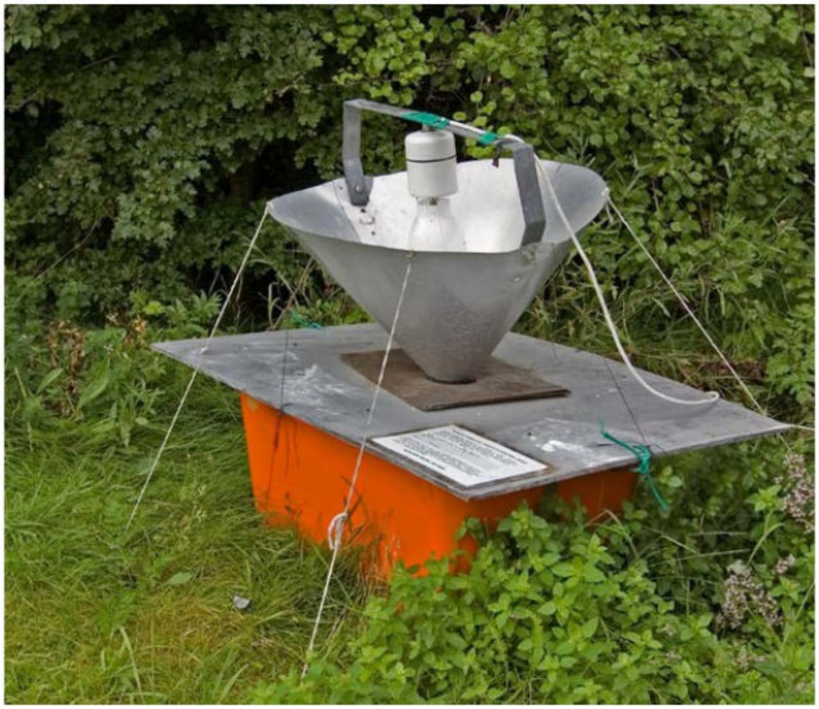
"Even though we have reported on population change in aphids, moths, ladybirds, wasps and general insect biomasses for decades, this new study represents a major advance in our understanding of the situation, with unexpected findings."

Driving force

Two of the most commonly suggested causes of 'Insectageddon' are agricultural intensification and, for night-flying insects like moths, light pollution. However, the researchers surprisingly found no evidence that agricultural practices or urban light pollution are the main driving force behind this recent decline.

The researchers categorised the moth trap sites into four land-use types: woodland, grassland, arable and urban, and found that land-use type (as well as changes over time in land-use) had little impact on the pattern of increase and decline in populations.

Dr Macgregor notes: "If pesticides were causing the problem, you would expect to see the biggest decline in arable landscapes; likewise, if it was light pollution, the biggest decline would be in urban environments. We found neither of these to be the case – in fact, the habitats with the biggest declines were woodland and grassland."



An insect light-trap, attracting insects which then pass down into the chamber below. Photo courtesy jps/www.shutterstock.com

The peppered moth *(Biston betularia)* has declined by 81% over the last 50 years, according to Rothamsted Insect Survey data. A characteristic of this species is that it can be incredibly well-camouflaged. This individual was photographed on a rock covered with lichen in South Wales' Alun Valley. Photograph courtesy Hugh Lansdown/www.shutterstock.com

Extreme weather events

Changing weather patterns and climate change could be an explanation, however, according to the researchers. Sharp increases in moth numbers during the late 1970s came soon after one of the hottest, driest years on record. Disturbance from extreme weather events can sometimes cause equally extreme and unpredictable population changes in insects, including both increases and declines.

Whether climate is contributing to the more recent decline requires further investigation; rising average annual temperatures and rainfall patterns did not match up with the peaks and troughs in moth populations.

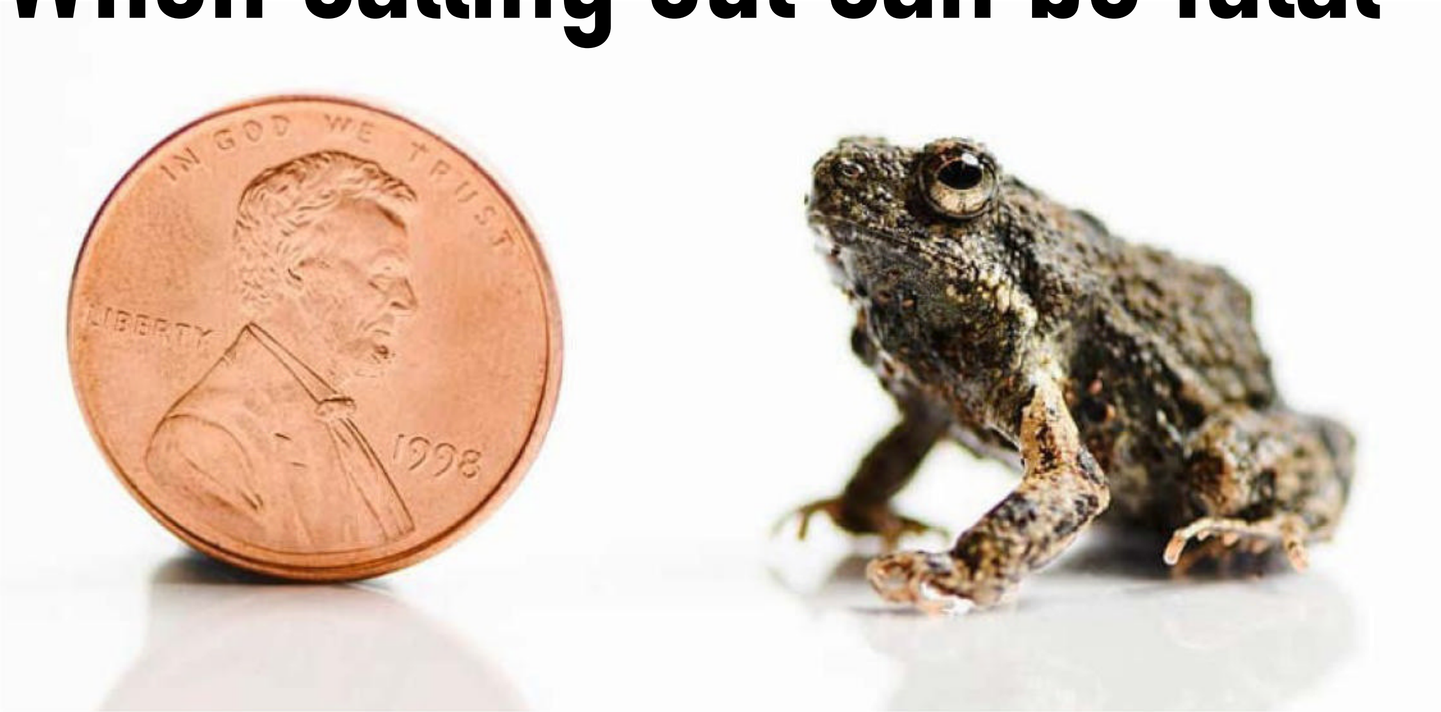
However, extreme weather events – from deluges and flooding to heatwaves and drought – are often not reflected in average climate records. The post-1982 decline appears to be real, but the researchers conclude that the reasons for this ecological decline are not as straightforward as often thought.

"There is no simple explanation, and more research on long-term data sets is required" added Professor Thomas. "We found that short-term studies and infrequent sampling can give erroneous estimates of biomass change. The complexity of insect population change requires more, better and longer-running data if we are to draw definite conclusions, particularly for parts of the world where insect data are limited."

Further information

Callum J. Macgregor *et al*. **Moth biomass increases and decreases over 50 years in Britain,** *Nature Ecology & Evolution* (2019). DOI: 10.1038/s41559-019-1028-6

When calling out can be fatal



▲ **These frogs are very small, measuring barely 2.5cm (1in) when fully grown.**

Photo courtesy Rebecca Wilcox/Purdue).

The túngara frog (*Engystomops* (formerly *Physalaemus*) *pustulosus*) is a tiny species found in parts of Central and South America. One of its main predators are midges, which are similar but smaller than mosquitos, although they can be just as deadly. Midges both feed on the blood of the frogs and are likely to transmit disease as they do so.

Repeated interactions

Túngara frogs and midges have probably been interacting since the Cretaceous period, more than 100 million years ago. Frogs and the midges that bite them originated in the same part of the world and have evolved together as they spread around the globe.

In these particular frogs, disease, predation and communication are intricately intertwined. Parasites are transmitted by midges, which find their way to frogs by detecting their mating calls. Given their solitary lifestyles, male frogs need to call to attract females, but in an ultimate catch-22, this also alerts predators to their whereabouts.

◄ **Ximena Bernal.**

Photo courtesy Purdue University.

An eavesdropping scientist

Ximena Bernal, an associate professor of biological sciences at Purdue University, has been studying this relationship for most of her professional life. She refers to the main line of her research as eavesdropping.

"We study how frogs communicate with one another, but also how their predators eavesdrop and exploit those systems," she explains. "The irony is that generally, the calls that female frogs prefer are also attractive to bats and flies. The poor males just can't win!"

The basis of Bernal's studies of these frogs and midges has also brought an unexpected benefit, helping in the development of novel trapping techniques to capture mosquitoes that are vectors of disease to humans.

Different calls

The mating calls that female túngara frogs prefer are relatively complex. A standard call is essentially a single whine, but males can add short bursts, or "chucks", to the call if they really want to stand out. The more chucks that are added, so the more attractive the call becomes, both to potential mates and also for possible predators such as bats and midges.

▲ **Bats such as the fringe-lipped *(Trachops cirrhosus)* will prey on túngara frogs, detecting their calls and homing in on their location.**

Photo courtesy Karin Schneeberger alias Felineora/CC BY 3.0.

Interestingly, the kind of call that male frogs use depends on where they live. Many wild animals adjust their behaviour when they move into urban environments; some birds learn to sing louder in order to be heard over the sounds of the city.

Similarly, túngara frogs that live in the city have more complex calls than their rural counterparts, according to previous research in which Bernal was involved.

Location affects behaviour

Yet this change in behaviour isn't likely only to be a response to city noise. It's now clear that these frogs call differently because they face fewer predators in an urban environment.

Bernal's team also wanted to know how long it took for frogs to change their behaviour in this regard. For the study, they moved more than 100 frogs either from the city to the forest, or *vice versa*, for at least four days.

Frogs from the forest didn't exhibit a noticeable change in behaviour during this period, but city frogs quickly realised that their complex calls would get them the kind of attention that they didn't want in the forest. They toned down their calls to factor in the threats posed by bats and midges.

"This means that in the city, sexual selection is intensified, and natural selection is relaxed, which leads to males using more complex calls," Bernal says.

Midges are really sensitive to both light and noise pollution, according to Bernal's research. They're nocturnal, which means they are most comfortable in the dark. In an environment where it's hard to escape fluorescent light, midges are rarely seen.

Midges are also sensitive to noise pollution - traffic noise interferes with their ability to detect frog calls and without this ability, so these insects cannot locate the amphibians.

The behaviour of these frogs is affected by their location. Photo courtesy Brian Gratwicke/CC BY 2.0.

⮝ Both midges and mosquitos feed on blood, and in the case of the túngara frog, the midges that attack these amphibians can spread a blood parasite that harms the frogs. Photo courtesy Mircea Costina/www.shutterstock.com

⮟ City lights are a strong deterrent to midges, and this in turn affects the behaviour of the frogs in more urban areas. Photo courtesy fuyu liu/www.shutterstock.com

The way that midges detect the frogs calling

But how these midges hear at all is somewhat of a puzzle. "At first, we thought they had a tiny tympanic ear, like a miniature version of an ear like ours. No one believed they could hear frog calls with just their antennae," explains Bernal. "But now, we think they just have really good antennae which they rely on for this purpose."

Midges are so tiny that they need to be on a slide, under a microscope to learn anything about their anatomy. Bernal's team recently discovered a new midge species, and in collaboration with researchers at Cornell University and the State University of New York, she's learning what sounds frog-biting midges can hear.

"We shine a laser on the antennae and observe how they move when we play different sounds. Using that information, we can learn which frequencies they're sensitive to," Bernal adds.

Although her lab is home to midges and a colony of roughly 100 túngara frogs, most behavioural observations happen in the wild.

Out in the field

During the summer, Bernal often makes the trek to Panama to work with students from Purdue and universities across Latin America. Sometimes they simply observe natural host-parasite interactions, but they also play back recorded calls and use sound traps to simulate different scenarios in the frogs' natural environment.

⮝ It's now thought that the antennae of the midges (seen here in close up) allow them to detect and localise the frog's position from its calls. Photo courtesy Maciej Olszewski/www.shutterstock.com

Findings from Bernal's laboratory range from revealing the collateral damage experienced by other frog species that occur around attractive túngara frogs as to why males from some frog species call in synchronisation with one another. Soon, she hopes to publish results on the effects of the blood parasite transmitted by midges – known as *Trypanosoma tungarae* – on the frogs.

"I want to show people how complex nature is," says Bernal. "People sometimes ask why the males don't just stop calling, and I'm like … 'It's all about sex. They need to mate!' And the predators take advantage of this fact."

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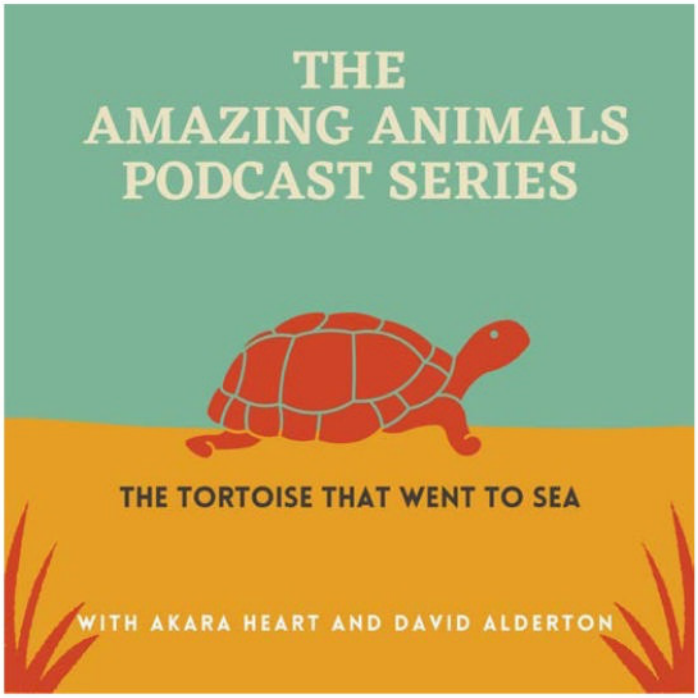
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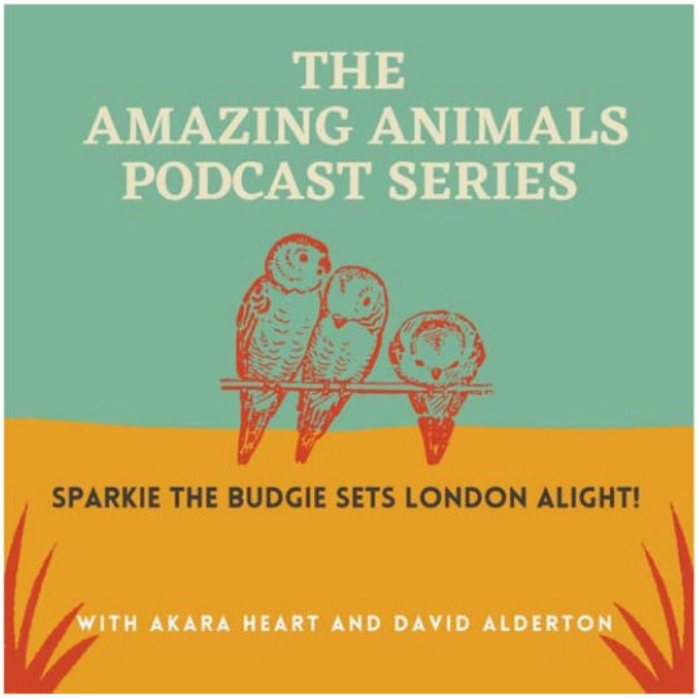
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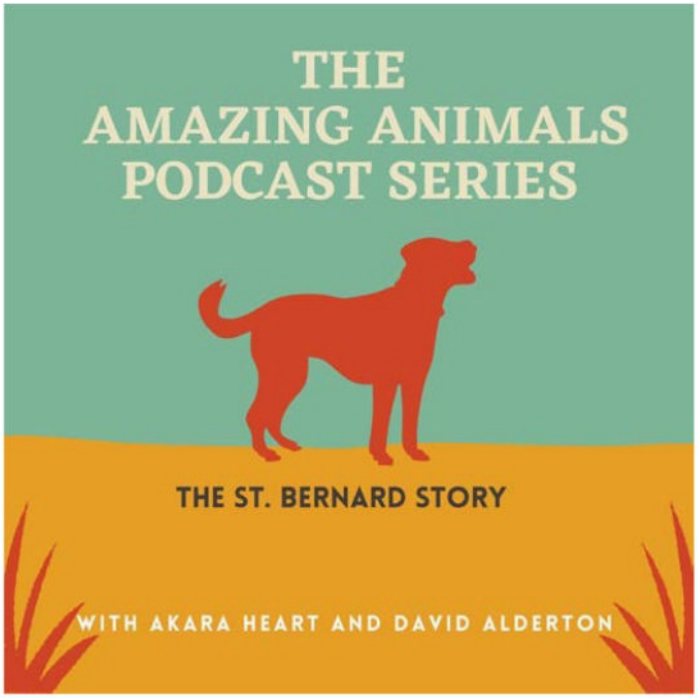
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